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YELLOWSTONE PARK.*

FROM San Francisco to Yellowstone Park the distance is so great that it would require an uninterrupted run of five or six days by rail to traverse it. We pass over a portion of the State of California, whose cultivated fields are wonderfully fertile, and, after crossing Mt. Shasta (15,740 ft. high) in a coach, take the cars again and travel through Oregon in order to reach Portland. Here we take a steamer for a trip on the Columbia, a magnificent river bordered with numerous volcanic rocks and basaltic columns, with snow-clad Mt. Hood looming up in the horizon like an immense pyramid. Then the cars are again taken for a run along Lake Pend Oreille, and to cross the interminable forests of Idaho and Montana, and follow the shores of Clark's River. Finally, the endless prairies of the same Territory come in sight, all stocked with horses and cattle, and then we reach the banks of the Missouri. The sight of all these interesting landscapes is enchanting, and there is no end of astonishment. We thus reach Livingston Station, where we take a train for Cinnabar. Here we enter a large six-horse wagon, and finally find ourselves in the heart of Yellowstone Park, at the mammoth Hot Springs.

This park, which is in the Territory of Wyoming, has an area of 3,575 square miles, inclusive of its great lake, which has an area of 330 square miles. The eternally snow-capped mountains called Teton Range have summits that reach 11,500 and 13,000 feet above the level of the sea. The lowest parts of the park itself are 6,500 feet above sea level. The mountains and soil of the park are of volcanic origin; but ages have passed, and we at present see the extraordinary vestiges of all the changes that have been effected by the caprices of nature.

Four years ago, the trip to Yellowstone Park was effected with some difficulty, but at

* From "Letters from America," published by A. Tissandier in *La Nature*.

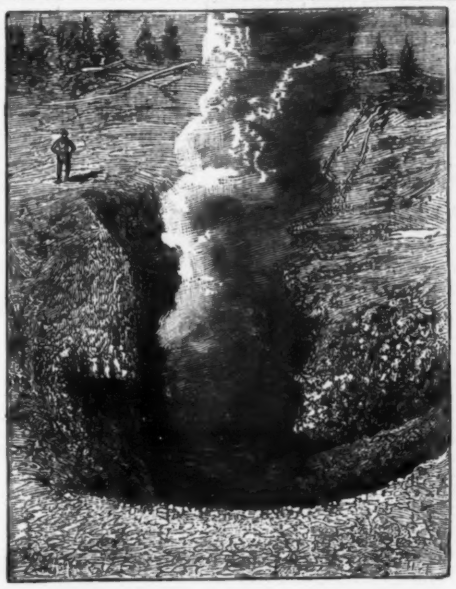


FIG. 1.—MUD VOLCANO IN YELLOWSTONE PARK.

FIG. 2.—MUD VOLCANO.

FIG. 3.—INTERIOR OF A SPENT BOILING SPRING.

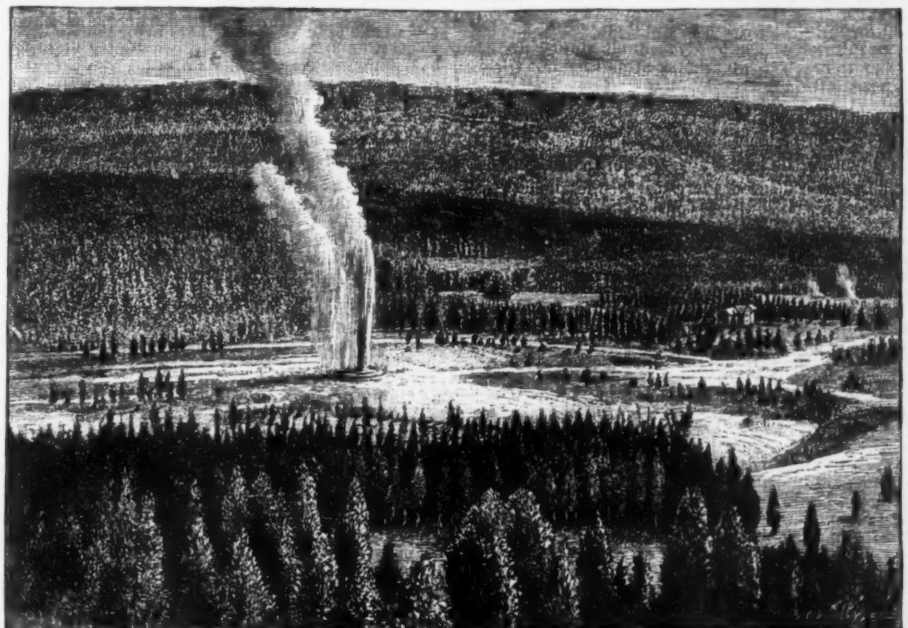


FIG. 5.—OLD FAITHFUL.

FIG. 6.—PULPIT TERRACE.

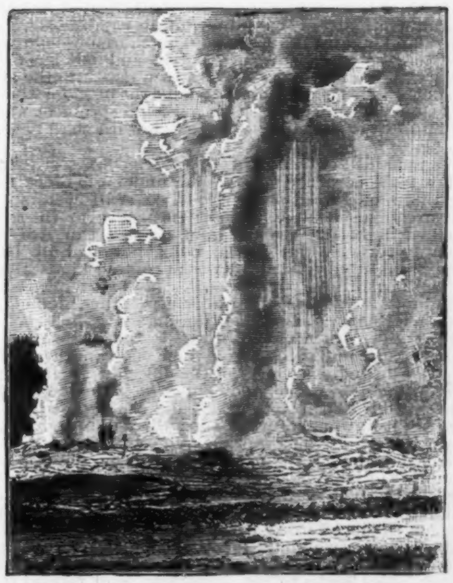


FIG. 4.—THE GIANT GEYSER.

ILLUSTRATIONS OF YELLOWSTONE PARK.

present, although the journey is lengthy, it no longer offers any trouble. The hotel is a large one, like a great caravansary, and is situated in one of the most curious spots in the park. Here we find the guides, horses, and provisions necessary for making interesting excursions. It is necessary to camp in the forests, and sleep in the open air, somewhat as on the Kaibal plateau (Arizona); but everything is easier here—there is water everywhere, and at the most celebrated localities there are rudimentary hotels where one can revictual, and even sleep if he choose. Two or three years more, and the Americans will be able to reach here with as much comfort as they now travel to Mt. Blanc or the Pyrenees.

Yellowstone Park, or rather that great territory as large as a department of France, is preserved by the Government, and is classed by it, so to speak, as we class our historic monuments. A keeper and nine assistants have charge of it. For important work, such as laying out roads, building bridges, etc., a requisition is made on the army for soldiers. These latter camp at the designated spot in the park, and perform all the labor. As hunting is expressly forbidden, birds and game can live in peace. Fishing alone is tolerated, and so the spot is a rendezvous for American amateurs who fish with the line, and who come hither for abundant catches of trout. People are always talking about the wonders of Yellowstone Park. The expression "wonders" is a truthful one if we understand thereby the hot springs, the canon, the solfataras, the geysers, the mud volcanoes, etc. These are unique things; and, as a whole, are something wonderful, unheard of, something that can be seen here only. But the aspect of the forests that must be traversed in order to go from one place to another, and the torrents and the cascades, are far from equaling those of the Alps or Pyrenees.

In order to see the at present known curiosities, twelve or thirteen days of exploration suffice. The gorges or canons of Yellowstone River are the first beauties to be visited. We camp right beside the rapids, amid the pine trees. The water flows in two superb lapses through the narrow channel excavated by it, and is inclosed by walls about a thousand feet in height. These walls are remarkable, and the rocks that compose them, calcined by volcanic action, have taken extraordinary colors. Sulphur yellow, ferruginous, greenish, violet, black, and snow white are scattered over the entire precipice in the most striking manner, and are of wonderful brilliancy, especially when the sun is shining. The emerald waters of the Yellowstone flow at the bottom of these strange abysses and a dark, thick forest of pines crowns all the rocks.

Following the edge of the Yellowstone River, we ascend to the very source—Yellowstone Lake, situated 8,000 feet above the level of the sea, with the Teton Mountains and the forests as a horizon.

On the shores of the lake, and on the route that we take to reach it, we remark numerous hot springs, solfataras, and mud volcanoes. The first that I sketched (Fig. 1) is very near the river. A thick, bubbling mud fills the bottom of the crater, which has a diameter of say 10 or 12 yards.

Dark steam escapes, and scatters numerous pellets of grayish mud on the walls, and these on drying assume the form of light, delicate, dentate stalagmites. The steam, on rising, lets fall a white, silicious powder, which covers the ground and neighboring trees. The vegetation then dies in the vicinity of the springs, but, a little further off, reasserts all its rights. It looks at times as if the ground were covered with snow, so dazzling is the silicious deposit. Near an ice-cold lake are seen the boiling springs, the emerald or azure tints of which are beautiful. A trout taken in the lake can be at once boiled in the springs, to the great satisfaction of the tourist. The hot water on flowing into the lake leaves on the ground traces of oxide of iron and sulphur of various shades of color, that plainly show the different strata with which it has come into contact in the bowels of the earth.

It takes quite a long time to traverse the forests on the way to Yellowstone Lake, in the upper basin of the geysers, and there are long stretches that sometimes get to be a little monotonous. We meet with wide areas covered with burned or dead forest trees before reaching the shores of Shoshone Lake. Then follow dense woods composed of pines almost all of the same size, and apparently of the same age. After a few hours' walk under all this thick and dark foliage, one gives up, in spite of himself, to a certain feeling of sadness. The ascents and descents multiply among the trees until finally my guide shows me some steam rising high in the atmosphere: we are in the geyser region.

The first thing we saw on reaching the Upper Geyser Basin was Old Faithful. It doubtless wished to celebrate our advent, for subterranean rumblings were heard, and almost immediately an enormous column of water rose to a height of 160 feet and fell back to the ground in fine drops. The steam rises into the atmosphere in a thick column to a height of more than 600 feet in calm weather. It is a solemn spectacle, and the impression that I have preserved of it I shall never be able to forget.

We remained two days in this vast geyser territory. A few tourists camped, as we did, under the pines on the shore of Fire-Hole River. The swift waters of this stream are heated in their passage over the silicious earth of the geysers, and no fish can live in them, because of the stream being poisoned by the sulphurous and volcanic deposits of all kinds that the boiling springs pour into it. We had a pleasant bath in it, however, and, under the pines, found a few revivifying cold water springs.

The upper basin of the geysers is the largest. One is pretty sure of coming across some of the natural jets of water during the course of the day, but their hour of spouting is variable, and cannot be indicated in advance. Old Faithful is exact, and it is possible to gaze at it in wonder every sixty-three minutes. The Great Geyser, its neighbor, spouts only about every twenty-four hours. We awaited the event along with a number of ladies and other tourists, all seated upon the white-carpeted silicious earth, and in almost the full glare of the sun, for we could not count upon the meager shade afforded by a few stunted pines. We waited nearly two hours for the moment of eruption, as one would await the going off of fireworks. The young ladies began to get impatient, and tapped the ground with the ends of their umbrellas. Finally the water gushed out, and rose to a height of nearly 190 feet for about ten minutes. The enthusiasm became general, and there were shouts of pleasure and admiration. A few instants afterward, we were attracted by the Splendid Geyser, at a distance of a few hundred yards. We quickly took to our horses, for we had to cross the Fire-Hole to reach the spot, and there was still time. The Splendid afforded us a few minutes of soul-inspiring contemplation. Its boiling waters rose to a height of over two hundred feet, and the thick steam, rising to the clouds and colored with rainbow hues at the hour of the setting sun, had a wondrous aspect. Aften ten or fifteen minutes, all became came quiet again. The water that had been ejected flowed off in rivulets, the crater of the geyser was empty, a few subterranean murmurs were heard, and then there was dead silence. Things were to remain thus for four or five hours, when there would be a new spectacle.

And so we passed the day running from one geyser to another. But Old Faithful had most success, and we beheld it by moonlight and sunrise. Tourists forget to sleep in this spot. Fig. 5 shows Old Faithful during its best moments. It is impossible to give the slightest idea of the grandeur of the pines that surround this geyser and of the snow-white plains that serve it as a base. There may also be seen in this sketch a portion of Fire-Hole River, and, amid the trees, a newly built hotel for the accommodation of those who do not wish to camp out in the open air in the forest.

On the morning of the following day, a quite rare pleasure was in store for us: the most beautiful of the geysers, the Giant, was to spout. This geyser ejects its water only about every four days. It is very irregular, and, although its boiling water does not rise to a greater height than that of the Splendid, the spectacle afforded is much more beautiful, since it lasts more than an hour and a half—sometimes three hours. Fig. 4 gives one of the aspects of this wonder. The steam, which rises to more than 900 feet in the atmosphere, sometimes obscures the sun; and its handsome crater, all incrusted with silicious deposits, disappears in the enormous mass of the water ejected.

It can be approached, nevertheless, by going to the windward of it. In this way one avoids a shower of boiling drops, that form on the ground a torrent of water and steam, which is lost in the Fire-Hole.

After passing through the lower geyser basin, and by the Gibbon or Norris Geysers, we reached the Mammoth Hotel Springs. These are not so large as the preceding, but the solfataras are more numerous here. They are associated with boiling springs, and form a sort of valley with azure lakes and smoking hills of fantastic appearance. We also entered the region of the "painted pots," or springs with colored borders. A few of the mud volcanoes here are remarkable. One of these (Fig. 2), which is of a pearl-gray color, ejects at every moment large pellets of mud to a height of three or four yards. Just alongside, another volcano is forming small bell-shaped silicious masses of a dazzling white, which burst and form a thick cream throughout the whole extent of the crater. The hotel is in the very center of the Mammoth Hot Springs. These immense boiling springs have, for ages, been forming deposits of silica and lime, which, accumulating stratum by stratum, have produced hills. The boiling water, continuously escaping from the bowels of the earth, flows along the sides of these artificial hills, and falls in cascades, and then in rivulets, into the Gardiner River. Pulpit Terrace (Fig. 6) gives a striking example of the aspect of these springs. But, unfortunately, a change is occurring, and this spot, the most beautiful of all, will soon fall into ruins. When the silicious deposits are kept up by small cascades of boiling water, they are hard and durable, but if the spring begins to give out they become friable, and are destroyed by the action of the rain and snow. Pulpit Terrace is in such a predicament, for the spring is giving out, and the handsome formations sculptured by the continual deposit of the waters is gradually falling into dust.

Quite near the Mammoth Hotel Springs it is possible to enter the interior of a long ago spent spring. The entrance is at first narrow, being about two yards in diameter. By means of two ladders, we reach at a depth of 65 feet an orifice through which we may penetrate still further by the aid of a rope. After reaching a depth of about 160 feet in this dark abyss, it is necessary to stop, for the sulphurous odors are suffocating. My guide gave me these details, for I did not go down.

The interior of this former spring (Fig. 3) is interesting. We distinctly see the strata of lime and silica that have been superposed with the flight of years, and the form of which is being gradually destroyed by moisture and the few green mosses that cover them. Nothwithstanding the at present universal reputation of Yellowstone Park, it is as yet annually visited by but few tourists, the number who see these wonders being only about two thousand per season. Our French Pyrenees and Alps are annually visited by from twenty-five to thirty thousand persons. It is true, however, that in this case the voyage is easier and the means of transportation are better.

ALGINE.

SEAWEEDS, fresh or dry, are put to soak in a dilute solution of carbonate of soda, which is afterward brought to 100 deg. C., the vessel closed, and the contents digested for about six hours at 110 to 115 deg. C. The product is strained; the insoluble part is chiefly cellulose in a peculiar condition. The liquid is now diluted with sulphuric or hydrochloric acid, which throws down the algine in the form of a gelatinous precipitate, which is collected, pressed, and dried in the air.

The mother liquor neutralized by a cheap alkaline earth, say lime, is decanted from any precipitate which may have been formed, and concentrated to the crystallizing point. Chloride and sulphate of soda separate; the remaining liquid is evaporated to dryness, and the resulting mass calcined. In the ashes thus obtained are bodies richer in iodine than those of ordinary seaweed.

Algine combines with bases to form salts which possess interesting properties. Alkaline alginates and the alginate of magnesia are soluble; those of ether bases are generally insoluble; that of cupric oxide is colored blue, of ferric oxide brown, etc.

ITS APPLICATIONS.

Alkaline alginates serve to weight muslins and to size stuffs. Magnesium alginate may be utilized as a mordant; the salts of zinc, copper, alumina, chrome, etc., render textiles and felted fabrics incombustible and impermeable. The salts of iron, nickel, copper, chrome, etc., form plastic masses, imitating horn; the salts of the alkalino-earthy bases may be made to resemble bone; the salts of ammonia or of soda mixed with gum lac have been suggested as a substitute for gutta-percha.

Soluble alginates act as substitutes for dung in Turkey-red dyeing; they may be employed as mordants. Combined with bichromate of potassa, algine does service in photography, and alone, or combined with soda, it furnishes with alkaline silicates a sort of malleable glass.

EARTH CURRENTS.

AT a recent meeting of the Berlin Meteorological Society, Dr. Weinstein spoke on the earth's currents which were observable in the telegraph wires by the disturbances they caused in the message service, their intensity at times exceeding that of the batteries of eighty Daniell employed for telegraphing. In order to the observation of the earth's currents, two equal metal plates had since the time of Faraday been sunk into the ground and connected by a wire, in which a galvanometer was intercalated. The deviations of the galvanometer needle might be induced as well by an earth current as by a current which arose from the contact of the earth plates with the earth. In the latter case, however, the current would be very weak when the plates were at a great distance from each other. The case being in point of fact otherwise, however, the currents in question were accordingly earth currents. The measurements of them were achieved by means of self-registering apparatus, either in the way of photography in England or mechanically in Germany; the earth current was conducted through a coil that, suspended in the interval between a rod magnet and a hollow cylinder magnet, was, under the oscillations of the current, drawn in or pushed out, and by means of a lever inscribed these movements on soot-blackened paper.

The direction of the current in the body of the earth was found by observation of two circuits forming a right angle with each other. In Berlin one circuit proceeded eastward toward Thorn, the other southward toward Dresden. The observations made in Berlin showed a direction of the earth's current from northeast to southwest, while in England the direction went more from north to south, with a slight deviation toward the east, and in France a direction from north to south, with an inclination toward the west, was observed. The earth current showed a perfectly regular daily variation. In the night, the earth current is slight; from eight o'clock in the morning it regularly increases, attains its maximum precisely at twelve noon, thence sinks rapidly till four P. M., whence it continues uniformly weak, not to revive till the following morning. A course precisely analogous to that of the earth current was manifested by the earth's magnetism, the connection of which with the electricity of the earth attracted attention from the very beginning, when disturbances made themselves observable.

To demonstrate with perfect precision the coincidence of the two phenomena, it was necessary to take for the purpose of comparison, not a single earth magnetic element, but the earth's total magnetism. The earth's electricity and the earth's magnetism showed, moreover, in their regular daily course their affinity, by the simultaneity with which their disturbances occurred. This simultaneity was so precise that in one case the distance between Berlin and Wilhelmshaven could be determined from the time when the disturbance of the earth's current made itself felt in Berlin and the time when the magnetic disturbance occurred in Wilhelmshaven. This simultaneity of disturbances at distant points of the earth pointed to a cosmical cause. Thus in August last year, at the very time when in Paris the emergence of an altogether unusual solar protuberance was observed, a magnetic disturbance was registered in Petersburg, and a disturbance of the earth's current in Berlin. The earth's current and the earth's magnetism showed further in common the periods of eleven years which coincided with those of the solar spots. In respect of the earth's current, this period could not indeed be demonstrated to a certainty, seeing that the regular observations made respecting it were yet of too recent date; but the regular course of the oscillations warranted the conclusion of a like period being drawn. A period of from two to five days, in which the earth's current and the earth's magnetism showed in their oscillations alternately larger and smaller amplitudes, had, in addition, been detected, although the explanation of the phenomenon was not yet forthcoming.

With reference to the question which phenomenon was the primary, the earth's current or the earth's magnetism, opposite views were entertained. The earth's electricity was assuredly not strong enough to magnetize the body of the earth; but, on the other hand, against the assumption that the earth's currents were induced by the oscillations of the earth's magnetism, an objection might be raised, namely, that in such a case the earth's currents would have to be proportional to the velocities of the oscillations of the earth's magnetism, and not to the oscillations themselves. This question can only be decided by further observations and by experiment. In a wide circle out of telegraph circuits the induction effects of the earth's magnetism might be studied and compared with the earth's currents. The speaker discussed the different theories of the earth's electricity set forth by Faraday, De la Rive, Lamont, Edlund, and the brothers William and Werner Siemens, without declaring himself decidedly in favor of any of them. In conclusion, he drew attention to the series of different jerks which showed themselves in the self-registering curve of the earth's currents on the occasion of every thunder storm. A jerk of this description on the part of the pointer seemed to correspond with each lightning flash.

CREDIT.

OUR engravings and descriptions of Watch without Hands, Wheel without Axle, and Antiseptic Vessel are from *La Nature*.

A PROJECT TO EXPLORE THE EARTH'S CENTER.

FROM Mr. J. J. Martinez, a scientist of the Argentine Republic, we have received a curious pamphlet, which cannot fail to excite attention. The following is what the author proposes:

"What is there at the center of the earth? Let us bore a hole in the crust and push forward toward the interior, in order to learn what phenomena occur there."

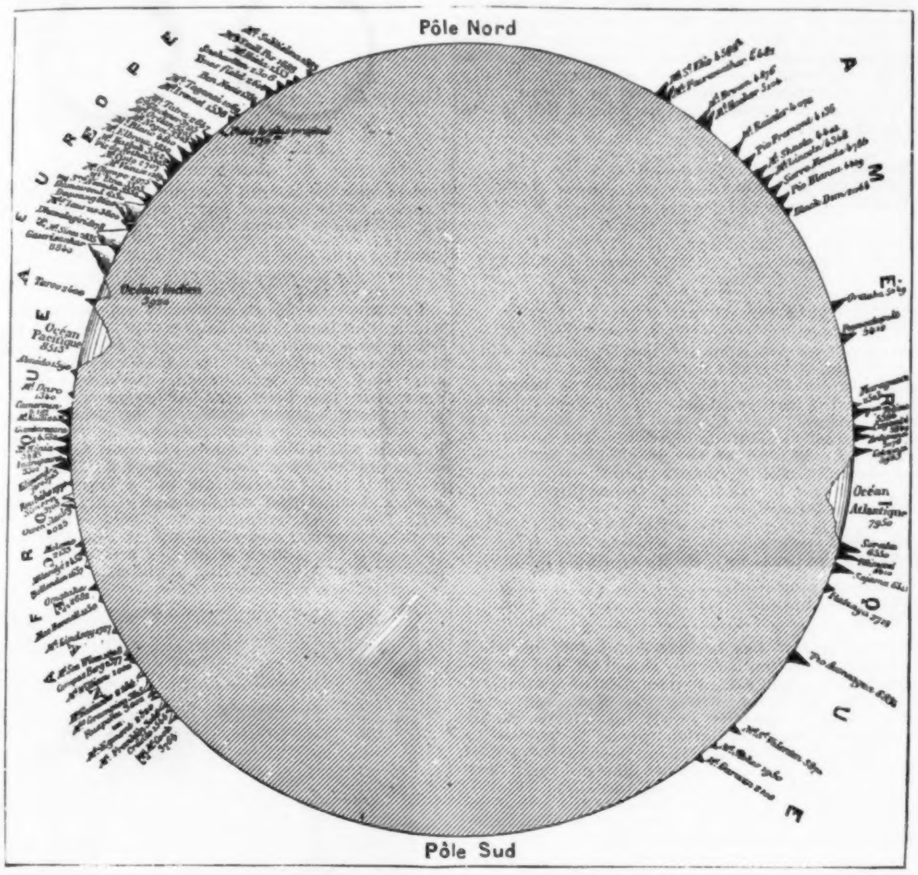


FIG. 1.—IDEAL SECTION OF THE EARTH. (Mountains exaggerated × 50.)

According to what he tells us, Mr. Martinez's first appeal was sent to all the learned societies of the world, and now the persistent geologist publishes a second one, in which he again urges the claims of his well for scientific observation. He proposes that all civilized nations shall unite in an effort to furnish the three or four million dollars that would permit of this great work being undertaken. "It is certain," says he, "that several generations will pass away before the center of the earth has been reached; but science ought not to work for the present generation only."

We know nothing of the interior of our globe, and the boring of a well of a depth exceeding that of all the shafts that have hitherto been sunk would assuredly offer considerable scientific interest; but when Mr. Martinez talks about going to the center of the earth, he does not seem to us to be conscious of man's feebleness and powerlessness. Suppose that all mankind

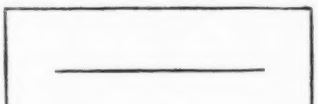


FIG. 2.—Line that would represent, on the scale of Fig. 1, the surface of the earth, with its highest mountains and deepest seas.

did devote its entire wealth and strength in the undertaking of such a job, it would reach but sorry results. In order to understand this, it will suffice to figure to our mind the globe such as it is. It has often been said that the earth may be compared to an orange, the depressions in the skin of which will represent the mountains and valleys. But this is not exactly true; the highest mountains of the globe, which are colossal masses alongside of a human being, are of so little account, in comparison with the earth's diameter, that they become almost inappreciable. The earth might be compared to a billiard ball rather than to an orange, for its surface would appear to be absolutely smooth and unbroken to a Micromegas who should be able to cast a glance at it. As for the deepest oceans, the would form but a liquid pellicle, which, likewise, would be imperceptible on the surface of the sphere. Fig. 1 represents the globe, whose radius is 3,956 miles, on a scale of one centimeter (0·39 inch) to 1,000 kilometers (600 miles). The relief of the mountains and seas that we figure had necessarily to be exaggerated fifty times in order to render them clearly visible. On this scale, it would have required the mountains and the depressions of the seas to be indicated in a line of $\frac{1}{125}$ of an inch, and of a thickness of that shown in Fig. 2. Thus, even in the reduced scale of our diagram, the highest mountains in the world disappear, and man, let us not forget it, is only about $\frac{1}{5000}$ as tall as one of these high mountains. At the top of the engraving we represent one of the deepest shafts that have been sunk up to the present. In order that the dimensions of this shall be on the same scale as that of the figure, it will be necessary to divide the line that represents it by 50!

Fig. 3 gives the heights of the greatest mountains and the greatest depths of the seas, on a scale of 1 millimeter (0·039 inch) to 1,000 meters (3,280 feet). On this scale, the center of the earth would be upon the prolongation of the line C D to a distance of 21 feet from the point C. It will be seen how sorry a figure again the deepest shaft (3,838 feet) presents.

Admitting that it were possible to sink a shaft four, five, ten times deeper, we should merely then slightly scratch the surface of the earth, whose depths, alas! will ever remain as little known to us as the heights of the heavens.

The earth is an immense sphere with smooth and unbroken surface, upon which the seas form a slight pellicle, comparable to that which would be formed, in comparison, by wetting a billiard ball with the finger. What becomes of man upon this ball moving in space? What become of his constructions and works? And what can become of Mr. Martinez's project for a shaft to the center of the earth?—*La Nature.*

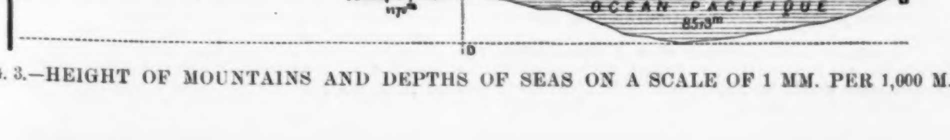


FIG. 3.—HEIGHT OF MOUNTAINS AND DEPTHS OF SEAS ON A SCALE OF 1 MM. PER 1,000 M.

INJURY TO FISH BY SEWAGE AND WASTE WATERS.

THE authors have made a series of very valuable experiments on this subject, which in England would have been rewarded with heavy fines, if not with imprisonment. They find that chloride of lime in proportions of 0·04 to 0·005 per cent. chloride have an immediate deadly action upon tench, while trout and salmon perish in presence of 0·0008 per cent. of chlorine. Sulphurous acid has the same action as chlorine, and is still more hurtful if another acid is simultaneously present. Sulphites are harmless.

Hydrochloric acid, 1 per cent. kills tench and trout. In sulphuric acid of 0·1 per cent., trout turn on their sides in two to six hours, while tench were not affected in eighteen hours. Acids are said to have less action, the higher are their molecular weights (?) Tannin at 0·1 per cent. is harmless. Ammonia exerts no action at 0·01 per cent. Soda at one per cent. is fatal to trout on prolonged exposure. Manganese chloride at 5 per cent. had no action on tench in twenty-two hours, and a trout sustained 1 per cent. for five hours. Iron acts as a specific poison upon fishes, but only in the state of a ferrous salt.

Alum has the same injurious action as the salts of iron. Solution of caustic lime has an exceedingly violent action upon fishes, due in part to the deposition of calcium carbonate in the gills. Arsenious acid, 0·1 per cent., combined with soda has no injurious action upon trout and tench. Mercuric chloride in proportions of 0·1 and 0·05 per cent. is immediately fatal. Copper sulphate 0·1 and 1·0 per cent. kills trout in a few minutes if they cannot escape into pure water. Potassium cyanide, 0·01 and 0·005 per cent., is rapidly fatal if there is no escape. Potassium sulphocyanide and ferrocyanide in the proportion of 1 per cent. had no injurious action in an hour.

Sodium sulphide, 0·1 per cent., was endured by tench for thirty minutes. The fish were strongly bleached, and did not recover their color in pure water. Hydrogen sulphide proved rapidly fatal in the proportions of 0·01 and 0·001 per cent. The hurtfulness of putrid sewage depends on poisonous gases, on the deficiency of oxygen, and on the action of bacteria.—*C. Weigelt, O. Sacre, and L. Schwab.*

COMMON COLORS AND POISONOUS COLORS.

THE following table of the composition of some of the colors in common use has been prepared by J. M. Thomson, of King's College, London. It will be found convenient for reference:

Common Name.	Chemical Name.	Composition.
YELLOW.		
King's yellow	Sulphide of arsenic	As_2S_3.
Cadmium yellow	Sulphide of cadmium	CdS.
Turner's yellow	Oxychloride of lead	$(PbCl_2 7PbO)$.
Turpeth mineral	Basic sulphate of mercury	$(HgSO_4 2HgO)$.
Chrome yellow	Chromate of lead	$PbCrO_4$.
Chrome zinc	Chromate of zinc	$ZnCrO_4$.
Citron yellow	Chromate of barium	$BaCrO_4$.
	Chromate of strontia	$SrCrO_4$.
Naples yellow	Oxides of lead and of antimony	$PbO+Sb_2O_3$.
Yellow ocher	Clay and hydrated ferric oxide	$(2Fe_2O_3, 3H_2O)$+Clay.
Mosaic gold	Sulphide of tin	SnS_2.
RED.		
Minium	Oxides of lead	PbO_2 3PbO.
Vermilion	Sulphide of mercury	HgS.
Purple red	Basic chromate of mercury	$HgCrO_4HgO$.
Iodine scarlet	Mercuric iodide	HgI_2.
Realgar	Sulphide of arsenic	As_2S_2.
Red ocher, Colcothar,	Ferric oxide	Fe_2O_3.
GREEN.		
Chrome green	Chromic oxide	Cr_2O_3.
Cobalt green (Rimmam)	Oxides of cobalt and of zinc	(CoO+ZnO).
Mountain green	Malachite green	$(CuCO_3CuOH_2O)$.
Scheele's green	Arsenite of copper	$CuOAs_2O_3$.
Verdigris	Basic acetate and copper	$[Cu(C_2H_3O_2)_2CuO 6H_2O]$
Emerald green	Acetate of arsenite of copper	$[Cu.C_2H_3O_2)_2CuOAs_2O_3]$
BLUE.		
Ultramarine	Silicate of alumina and soda with sulphide of sodium	$Na_2Al_2Si_2O_8 2NaS$.
Mountain blue	Malachite blue	$(2CuCO_3CuOH_2O)$.
Smalts	Silicate of cobalt and potassium	CoK_2SiO_4.
Antwerp blue, Insoluble Prussian blue,	Ferric ferro-cyanide	Fe_4Cy_{18}.
Soluble Prussian blue	Ferro potassic ferro-cyanide	$K_2Fe_2Cy_{12}$.
Indigo		$2(C_8H_5N_2O_2)$.
BROWN.		
Manganese brown	Binoxide of manganese	MnO_2.
Vandyke brown	Ferric oxide	Fe_2O_3.
Burned sienna, Burned umber,	Clay colored with oxides of iron and manganese	....
ORANGE.		
Chrome orange	Basic chromate of lead	$PbCrO_4PbO$.

CLASSIFICATION BASED ON POISONOUS PROPERTIES.

The following grouping, always interesting, is the more so now that many are indulging in what the London *Chemical Review* very properly characterizes as the "poisons outcry."

1. *Colors Dangerous to Health.*—Orpiment, realgar, binodide of mercury, turpeth mineral, arsenite of lead, white lead, litharge, minium, Naples yellow, oxychloride of lead, arsenite of cobalt, verdigris, Scheele's green, Prussian blue, Prussian green.

2. *Colors Less Dangerous to Health.*—Chromate of lead, vermilian, sulphide of tin, mineral lake (chromate of tin), chromate of copper, purple red, Thenard's blue, oxide of zinc, chromate of zinc, chromate of barium, oxychloride of antimony, sulphide of cadmium, smaltz, ultramarine.

3. *Colors not Dangerous.*—Sulphate of barium, yellow and red ochers, Venetian red, cochineal, manganese brown, vandyke brown, raw and burned umber, raw and burned sienna, sepia, ivory and lamp black, indigo, colcothar, green earth.

REDUCING AND INTENSIFYING NEGATIVES.

IN the *Photographic News*, Mr. W. M. Ashman relates his experience with different reducing agents, and comes to the conclusion that E. Howard Farmer's red prussiate of potash method is superior to all others on account of its simplicity and certainty of action. The solution is made as follows:

Water	16 ozs.
Red prussiate of potash	480 grs.

A few drops of this solution is added to an ounce of hypo fixing bath, and this is directed to be diluted with four times its bulk of water. Over-dense negatives are immersed therein until the requisite reduction has taken place, when they are washed in water and dried. The chemical action which occurs is that of converting a portion of the image into silver ferro cyanide, which dissolves in hyposulphite of soda solution.

Since this method has been introduced, it has made many fast friends among experts, both amateurs and professionals, and eau de javelle, ozone bleach, and other combinations of lime with chlorine, as well as the cupric compounds, have been cast aside by the writer, among others, in favor of the red prussiate of potash and hypo plan. It is only fair to mention, however, that it has in some hands one failing, that of staining the gelatin an evident yellow, a color familiar to all who are acquainted with yellow prussiate of potash in solution; and the formation of this compound is really the cause of the yellowness. Any apparent disadvantage which is thought to arise from this source may be readily overcome by the agency of an acid clearing so-

lution, which quickly destroys the color to all appearance, although we shall presently show that it is possible for it to reappear.

As the acid treatment, it should be noted, acts with great energy in removing both the color and some of the density at the same moment, its employment should be attended with caution, and when it has been decided upon that an acid clearing solution shall follow, it will invariably be found advisable to apply the same in a diluted state; that is to say, the ordinary solutions employed may be diluted with three or four times their bulk of water, and the previous reducing action ought not to be carried so far as would be the case were the acid omitted.

Preparations of ferrous sulphate and acidified alum should not be used for the purposes above suggested, as they impart a general inky stain throughout the film, which can only be removed with difficulty. Negatives that have in this way become spoiled for printing may generally be saved by a short immersion in the photographer's wet plate fixing bath (potassium cyanide), which changes the black stain into a somewhat richer yellow than it appeared before the application of the ferrous compound, and the density is not appreciably changed thereby.

Plates that were absolutely black by transmitted light, due to prolonged development, were first soaked in water for some time to soften the film, after which an immersion in the ordinary hypo fixing bath took place, in order that this agent might penetrate the film, and thereby assist the action which was to follow. In due course the negatives were transferred to another vessel containing 2½ per cent. solution of red prussiate of potash, one part of the salt to 40 parts of water, and the dish was kept in gentle motion for several minutes, when a material reduction was seen to have taken place; those portions only which had originally frilled in development again becoming loose.

The action then appeared to cease, although too much density yet remained. As the negatives were of value, it was deemed advisable at this stage to adopt all necessary precautions, and the remaining excess was removed by alternately dipping each negative into separate diluted solutions of hyposulphite of soda and red prussiate of potash. Had there been no indications of frilling, the same result might have been accomplished in less time, also minus a yellow tinge, already referred to, which now pervades some of the films, by soaking the negatives, after the first reduction was observed, in acidified alum solution. This, however, was thought to be a little risky, and therefore abandoned.

Sufficient has been brought forward in the foregoing practical experience of this method of reducing to enable any one who may be interested to form his own opinion upon its value. Among its capabilities may also be mentioned that of reducing gelatine positives which are too thick for the illuminating power at disposal in some lanterns. Overprinted proofs on ordinary sensitized paper are in like manner amenable to similar treatment, but, like every other plan recommended for this purpose, it is open to question whether the most effective process is not a hasty destruction of the print.

An acquaintance with a reliable method of increasing the density of a gelatin negative is of no less importance than that which formed the subject of the previous remarks, although it must be admitted that with plates of improved manufacture, and a larger experience in their manipulation, the every-day worker finds himself seldom called upon to put his knowledge of intensification into practice.

The methods which have been recommended for the purpose of increasing opacity are many and various, the details concerning all of which it will scarcely be worth while to enter upon here, since practical experience has become well nigh agreed upon the chemical plan of bleaching the image with mercuric chloride alone, or associated with a soluble chloride, bromide, or iodide.

The process, as our readers are aware, is based upon the properties of metallic silver and mercuric chloride to mutually react upon each other, and thus effect a chemical change, whereby the mercuric salt loses a portion of its chlorine, which is attracted to the silver to form silver chloride, and the mercuric salt is reduced to mercurous. Bichloride of mercury becomes changed into calomel, a salt readily reducible to a state of black oxide or sub-oxide when acted upon by ammonia solution, ordinary lime water, and other agents. When a saturated solution of bichloride of mercury is permitted to react upon an ordinary gelatin negative, the film quickly becomes white, which in practice is termed bleaching.

The real or printing opacity of such a film at this stage is considerably less than it was before the treatment commenced. This is due to the increased facility offered to the passage of light, and if it were attempted to print from a negative in this condition, the proofs would be wanting in vigor. In order, then, to overcome this peculiarity, various agents have been suggested and used, some of which possess the property of dissolving the whole of the converted silver chloride, and blackening the mercury compound, as instanced with ammonia, etc.

One of the chief requirements of the process appears to be effectual washing before and after immersion in the bleaching solution; and if this is not very thoroughly carried out, failure, sooner or later, is sure to ensue. Those who can give their negatives the requisite degree of washing would do well to adopt Monckhoven's plan of darkening the bleached image with silver cyanide, as this agent is extensively used at home and abroad by expert photographers, and, so far as the evidence at present goes to show, negatives carefully treated in this manner do not change by storing. Dr. Monckhoven's proportions are as follows (480 grs. to each oz. of salt):

No. 1.

Mercuric chloride	1 oz.
Potassium bromide	1 oz.
Water	40 ozs.

No. 2.

Silver nitrate	1 oz.
Distilled water	20 ozs.

No. 3.

Potassium cyanide	1 oz.
Water	20 ozs.

The cyanide of potassium solution is gradually added to that of the silver, and a dense precipitate of silver cyanide occurs. When this precipitate is nearly all redissolved, the further addition of No. 3 should cease.

Washed negatives are bleached in No. 1 solution, and again well washed before immersion in the mixture of Nos. 2 and 3. As soon as the blackening action has taken place, it is well to remove from the solution and wash; otherwise, by continuing, the acquired density will be again reduced.

Preference is given by the writer to Scolik's method of mercurial intensification, wherein the image is bleached in the usual way, Scolik's formula being:

Mercuric chloride	1 oz.
Potassium bromide	1 oz.
Water	50 ozs.

When a negative has become completely bleached, the mercurial solution is merely rinsed off, and the film is immersed in a half saturated solution of neutral sodium sulphite in water, where the darkening action steadily, though somewhat slowly, takes place. Should the negative upon examination appear to possess too much density, either bleaching has been carried too far, or immersion in sodium sulphite has not been sufficiently prolonged to dissolve all the silver chloride. Fortunately, the remedy is to continue the action, and to increase, if need be, the strength of the sodium sulphite employed. It should be noted that the undissolved silver chloride may generally be observed upon examining the back of the negative (in the case of glass plates), when a light colored veil will be noticed to be gradually disappearing.

One considerable convenience of this plan over others arises from the circumstance that an extremely limited washing is required at any stage, and it is by no means an uncommon practice to commence bleaching negatives that require intensification after they have received a very meager washing away of the fixing solution, while, as before stated, a rinse between the mercury and sodium sulphite solution is all that appears to be needed at that stage, and moderate washing afterward completes the work.

Negatives intensified in this way present a smooth surface when dry, which contrasts favorably with any other plan, for, in the writer's experience, all others have a tendency to dry more or less rough and absorbent to varnishes, which makes such surfaces undesirable to retouch upon.

FOUQUE'S PHOTOGRAPHIC SEISMOGRAPH.

THE accompanying engravings explain an ingenious apparatus devised by Mr. Fouque for facilitating the study of seismic movements. It consists essentially of a mercurial bath, which is placed upon the ground, and upon which falls a fascicle of intense luminous rays coming from a Trouve's or a magnesium lamp. Between the bath and the source of light there is a converging lens. The rays reflected from the mercury form an image upon a plate sensitized with gelatino-bromide of silver and inclosed in a camera of peculiar construction. A clockwork gives this plate a rotary motion, so that the image of the luminous point describes a circle. If the mercury be motionless, the circle will be regular; but if its surface be shaken, the luminous point will be unequal and be reflected at places.

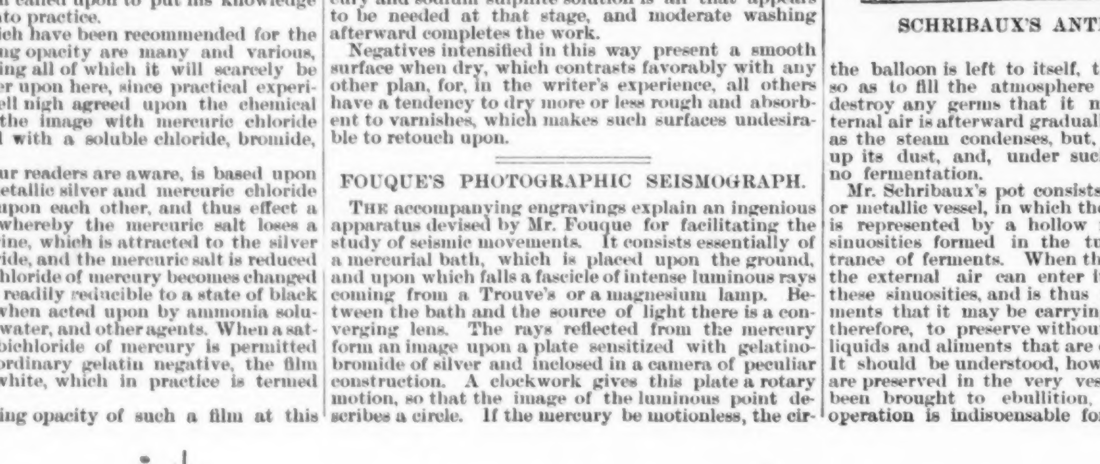


FIG. 1.

The camera is so arranged that it closes before the plate has made an entire revolution, without which the two images would be superposed. To this effect, two shutters are placed one over the other. The upper one of these drops at the end of a given time, under the action of the clockwork, and closes the aperture of the camera.

The apparatus is very sensitive, and gives valuable indications. Fig. 2 represents the curve traced upon the sensitized plate when the neighborhood is undisturbed, and the ground is struck. Fig. 3 shows what happens to the regular curve when a carriage is passing.—*Chronique Industrielle.*

FIG. 2.

FIG. 3.

AN ANTISEPTIC VESSEL.

THE annexed figure represents an antiseptic pot, which has been patented by Mr. Schribaux, and which is so arranged as to prevent the fermentation of such putrescible liquids as may be put into it after they have been boiled. By means of it, Mr. Schribaux has been enabled to preserve ordinary meat broth without alteration for nearly a month. It is based on the same principle as the glass balloons in which Mr. Pasteur preserves ferments without alteration for an indefinite period. These vessels, it will be remembered, are not wholly closed, but have a channel that communicates with the external air. Their neck terminates in a tube which is open at the extremity, and which the air can freely penetrate; but this tube is so shaped and arranged as to prevent dust from entering at the same time. Before

SCHRIBAUX'S ANTISEPTIC POT.

the balloon is left to itself, the liquid is boiled in it, so as to fill the atmosphere with its steam and to destroy any germs that it might contain. The external air is afterward gradually introduced in measure as the steam condenses, but, as just stated, it gives up its dust, and, under such circumstances, causes no fermentation.

Mr. Schribaux's pot consists of a cylindrical earthen or metallic vessel, in which the above mentioned tube is represented by a hollow rim containing all the sinuosities formed in the tube to prevent the entrance of ferments. When the pot has its cover on, the external air can enter it only by following all these sinuosities, and is thus freed from all the ferments that it may be carrying along. It is possible, therefore, to preserve without alteration the various liquids and aliments that are capable of being boiled. It should be understood, however, that these latter are preserved in the very vessel in which they have been brought to ebullition, since this preliminary operation is indispensable for purifying the volume of air which is to remain in permanent communication with the liquid to be preserved.

As may be seen, says *La Nature*, from whom this description and cut are borrowed, Mr. Schribaux has here made a very interesting application of the theory of ferments, and his pot would appear to be called

upon to render signal services in domestic economy, especially in the country, where it is often necessary to preserve broth and other food for quite a long time. The model shown is merely a trial specimen. Mr. Schribaux is now studying out the final form to give it before putting it in the market.

SIBLEY COLLEGE LECTURES.—VIII.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

By CHARLES T. PORTER, of New York.

PRINCIPLES INVOLVED IN THE CONSTRUCTION OF HIGH SPEED ENGINES.

INTRODUCTION.

THE decade between the years 1850 and 1860 was signalized in this country by a remarkable direction of engineering thought and inventive activity toward the subject of mechanical devices for working steam expansively. Among mechanical engineers the cut-off was the universal theme. This was then regarded as the single panacea for the consumption of steam. The great loss from condensation in the cylinder, a loss which increases directly with the increase of pressure admitted to the cylinder, and the percentage of which increases with every advance of the point of cut off toward the beginning of the stroke, was, so far as this country was concerned, not yet thought of. (See note at end of the paper.)

The methods tried and the devices produced for expansive working were surprisingly numerous. I remember a humorous suggestion, made to the editor of the SCIENTIFIC AMERICAN, that he should change the name of his paper to the *Weekly Valve and Cut-off*, on account of the regular supply of illustrations of this character.

Among these devices, the liberating valve gear came rapidly to the front. The liberating system was the invention of Frederick E. Sickles. Mr. Sickles patented the trip cut off in 1842. The application of this invention was confined to puppet valves, which, in opening and closing their ports, move in the direction perpendicular to their seats. These valves, in their two seated, or nearly balanced, form, were at that time, as they still continue to be, in universal use on the engines of paddle-wheel steamboats navigating our Eastern waters. The Sickles cut-off was extensively applied on those engines, and is still in use on many of them. On stationary engines only a few applications of the Sickles cut off were ever made.

In this invention, the valve is released at any desired point of the stroke, as fixed by the engineer, and is permitted to fall to its seat; its fall being accelerated by a spring or by atmospheric pressure. The valve is prevented from striking its seat injuriously by the device known as "the Sickles dash-pot." This is a vessel in which a piston, the stem of which is rigidly connected with the valve stem, rises and falls with the valve. In rising, this piston leaves a vacuum beneath it. In falling, it strikes a body of water. The surface of this water is kept nicely adjusted to the point at which the piston striking this surface arrests the valve as it touches its seat, and prevents it from striking a blow upon it. The inventor availed himself of the incompressibility and the indestructibility of water.

No inventions more important or fruitful than these adorn our engineering history. The gain made by them was, effecting a sharp cut off of the steam, in place of wire drawing, as it was called, or the fall of pressure in the cylinder by the advance of the piston, while the valve is gradually closing the port. The slide valve, as well as the puppet valve, previous to this invention, always produced this wire drawing, sometimes in an extreme degree, unless the engine was moving quite slowly.

Mr. Corliss obtained his original patent in 1849. He applied the two above described inventions, of liberating the valve, and catching it in its fall, to valves which move in the direction parallel with their seats. In place of water he substituted air, to form an elastic cushion instead of a solid resistance, for catching the valve. This he could do, because in this class of valves, the closing movement does not need to be arrested at a definite point. He applied the common governor to the liberating mechanism, to vary the point of liberation automatically as required by the resistance, and invented the elegant and useful device known as the Corliss wrist plate, by which the movement of each valve is reduced and retarded while the port is covered, and the valve is moving under pressure of the steam.

Mr. Corliss employed a falling weight to give to the valve its closing movement when liberated, and also a spring and subsequently the pressure of the atmosphere, to accelerate this movement. At the works of Shepard & Co., in Buffalo, N. Y., Mr. Corliss found a valve made to slide with a rotating motion on an internal cylindrical seat. This valve was adapted to his requirements in a remarkable manner, and was adopted by him, and has always maintained its position in these engines. By means of this combination, Mr. Corliss created that monumental success, the "Corliss Steam Engine."

A number of other applications of the same general system were also made during this period, and the liberating valve gear with automatic variation of the cut-off, came gradually to be regarded as the only means for working steam economically, and at the same time maintaining regular motion.

In the year 1860, John F. Allen showed me, with a piece of chalk, his system of valve gear and valves; and expressed the opinion that, in combination with the central weight governor, which I was then introducing, it would enable an automatic variable cut off to be got with positive movements of the valves, as good as that given by the liberating valve gear; while it would be free from the defect inherent in that system, which is, that the closing movement of the valve has no relation to the speed of the piston, but is the same for all speeds.

In examining Mr. Allen's chalk marks, I became impressed by the remarkable adoptation of the novel system which they presented to the requirements of high speed short stroke engines; and it seemed to me that it would be a great step in advance, to employ rapid revolution of the shaft, and thus get a large amount of power from a small engine. Mr. Allen did not share my high speed enthusiasm, but wanted his system compared with the liberating valve gear, turn for turn.

I was, however, convinced that, with its four openings for admission, and the speed of the closing movement of the valve increasing directly with that of the piston, this system would enable a sharp cut off to be made at speeds far beyond those at which the liberating valve gear would work at all, and that in this capability lay its real value.

The first engine made was one of 6 in. bore of cylinder, by 18 in. stroke. The designs for this engine were prepared by Chas. B. Richards, now Professor of Dynamical Engineering in the Sheffield Scientific School, Yale College. Mr. Allen invited Mr. Richards and myself to visit the engine room of H. A. Burr's hat factory in the city of New York, where he was in charge of a pair of beam engines, fitted with the Sickles valve gear, and making 25 revolutions per minute. He took for us diagrams from one of these cylinders, which were the first indicator diagrams either of us ever saw taken. At that time, very few persons in this country were acquainted with the use of the indicator, which was adapted only for moderate speed of the engine.

Mr. Richards had just commenced work on the drawings for this little engine. The question at once presented itself, How is this engine to be indicated, at its intended speed of 160 revolutions per minute? I said: "Mr. Richards, you must get up an indicator for us." At the end of six months, after having exhausted several unsatisfactory schemes, Mr. Richards produced a drawing which he thought would answer the purpose. From that drawing I had an indicator made at the Novelty Iron Works, in New York, and when the 6 in. by 18 in. engine was ready for trial, the indicator was ready also. This was the origin of the "Richards indicator."

This little engine made such a good diagram, and was so economical and regulated so well, that I determined to make an effort to introduce the system to public notice, by the exhibition of a larger and better engine, of 8 in. bore of cylinder by 24 in. stroke, at the approaching Universal Exhibition, to be held in London in 1862. The time for preparation was short. After having made my application for space, I was waited upon by Mr. Joseph E. Holmes, Assistant United States Commissioner. I had nothing to show Mr. Holmes pertaining to my proposed exhibit, except drawings and partly finished patterns. But I showed him the little 6 in. by 18 in. engine at work, at its then astonishing speed, and brought his admiration up to boiling point by taking with the wonderful new indicator, sharp cut off diagrams from it, with scarcely a vibration in the expansion curve. The steam was following to nearly the middle of the stroke, which explains this excellence. It afterward appeared that Mr. Holmes became deeply impressed with the importance of my proposed exhibit.

The date drew near at which the engine must be sent in. Mr. Holmes had left with a cargo of exhibits. I found it would not be possible to complete the engine here in time, and determined to send the bed plate by steamer, so as to secure the space, and forward the remaining parts as soon after as possible, and construct the engine on the spot. In two weeks after sending the bed plate I made two more shipments, and then took passage myself, leaving a final shipment to follow. The way was opened for me in a remarkable manner.

Mr. Wellington Lee, of New York, was then in London engaged in introducing the steam fire engine, of which he had been the first successful builder in this country. On arriving in London, I drove to Mr. Lee's lodgings, in search of the information which a stranger would need. In a fit of exasperation over the Mason and Slidell affair, Congress had repealed the act making an appropriation for the expenses of the United States Exhibit, and Secretary Seward had issued a proclamation dissolving the commission. Mr. Lee gave me the following interesting account. The news of this action of our government had reached London before Mr. Holmes' arrival, and the demand for space in the Exhibition was so pressing that the Imperial Commission had confiscated the United States space, and apportioned it among other nationalities, chiefly English.

Mr. Holmes had, however, influential friends, and it was quickly made to appear to the Imperial Commission that they had acted on a newspaper rumor, without any official notification. Mr. Seward had notified all the world *except* the Imperial Commission. Mr. Holmes was at their door with a ship load of exhibits, and his official documents complete and regular. The Commission did all they could do by way of reparation. They authorized Mr. Holmes to take possession of any space in any department not actually occupied. In this way he had succeeded in locating every exhibit with the single expection of my engine.

He had, however, a few days previously, heard that an engine, which had been procured by the Commission for the purpose of driving the weaving machinery in the British section had been rejected by Mr. D. K. Clark, the superintendent of machinery, and he had at once made application for the place. In reply to Mr. Clark's inquiries, Mr. Holmes had gone so far as to give his personal assurance that the engine would be there, that I would be there, and that the engine would be everything he could possibly desire; and on the strength of this assurance he had secured the place. I always thought that Mr. Clark was captured by the story of the new indicator, in which he afterward showed the deepest interest. "Mr. Lee," I replied, "all that seems like a remarkable ordering of Providence. Now I have, or expect to have, the pieces of an engine, no two of which have ever yet been together, and have got to build the engine here." Mr. Lee looked grave. "Well," he said, after a few moments' reflection, "come with me, and I will introduce you to Easton, Amos & Sons, an eminent engineering firm, who are building my steam fire engine." We met one of the junior members of the firm, Mr. James Easton. After hearing my story, Mr. Easton extended his hand, saying, "That is one of the most plucky things I have heard of. I like it. We will build that engine for you, sir. All the resources of this establishment are at your service." I had not then been in London three hours. "Now," said Mr. Lee, "I think Mr. Holmes would like to see you." I soon found my way to the Exhibition Building at South Kensington, searched out Mr. Holmes, and accompanied him to Mr. Clark's office. As he opened the door, Mr. Clark looked up with this salutation: "Good morning, Mr. Holmes. Where is that engine?" I never felt greater satisfaction than afterward in redeeming Mr. Holmes' extraordinary undertaking in my behalf.

The construction of the engine was successfully accomplished, and it ran in the most perfect manner from the start, at 150 revolutions, or 600 feet piston travel per minute; which was by far the highest speed that had then been successfully attempted in Europe with a stationary engine.

It is difficult now to imagine the unheard of character of that speed in stationary engines at that time. Locomotive engines were running on some of the British lines very nearly, if not quite, as fast as they now are; but that did not seem at all to convey to English engineers the idea that it was possible to run stationary engines at such speeds.

In one of our first interviews, Mr. Clark asked me how fast I was going to run the engine. My reply seemed almost to take his breath away. "But, but," he said, "have you had any experience with such a speed as that?" I told him my little experience. "Well," he said finally, "I cannot allow such a speed here. I consider it dangerous. You may run at 120 revolutions a minute, but no faster." Now Mr. Clark was a railway engineer, and was at that time the leading authority in England on railway machinery. I settled in an instant in my own mind the question whether or not I should sacrifice the sole object of my exhibition. Acquiescing meekly in Mr. Clark's command, all the same I proceeded to order the pulley for a speed of 150 revolutions per minute, trusting to the engine for my vindication.

When steam was turned on, the engine started off at this exact speed, running as smoothly and silently, and free from vibration, and cold in its bearings, as any ever made since. It had not been running long before I saw Mr. Clark coming from his office with his watch in his hand. He made his way through the crowd, and advancing close to the engine, observed it for some time carefully, and then counted it through a full minute. Then he turned and gave me a very comical look, and said, "Ah! Porter—but, it's all right. If you will run as smoothly as this, you may run at any speed you like."

No better indicator diagrams were ever taken than those given by that engine. This, so far as the admission line was concerned, was due in part to the ample area of steam pipe by which the pressure was maintained in the steam chest. A short 3 inch pipe connected with a very large steam main that ran under the floor. The area of this short pipe was 14 per cent. of the area of the cylinder.

A few days after starting, I had a visit from the jurors. Professor Rankine was secretary of the Board. The other jurors soon became engaged in an animated discussion of the question whether the piston in the little engine was not moving so swiftly as to get away from the steam. The diagrams showed early and sharp cut off, and of course sudden fall of pressure; quite in contrast in these respects with any diagrams the jurors had ever seen before; and to some of them this seemed to show that the speed of the piston caused the steam to fail of exerting its full pressure. I well recollect the quiet but authoritative manner in which Professor Rankine arrested the discussion, with the remark, "There is no limit to the speed at which steam will follow a piston."

The engine grew in favor. At the close of the Exhibition it was purchased by Easton Amos & Sons for their own use. They almost took *my* breath away, by asking me if I had any objection to its being run at 220 revolutions per minute, but of course I hadn't any. The engine was set to run at that speed, and drive a foundry fan at about 2,000 revolutions per minute, through frictional gearing, wheels nine to one.

After the engine had been delivered, Mr. Amos, senior, said to me, "Porter, where is the pump?" "The engine has no pump," I replied. "No pump!" he exclaimed, with a look of amazement. "No," said I; "in our country we consider the pump an attachment to the boiler; we don't run pumps at such speeds, and would regard them as out of place on an engine, whatever its speed." "Well," he replied, with an expression of intense disgust, "if a man should sell me a musket, and tell me it had no lock, stock, or barrel, these were all extra, I should think it just about as sensible." You see, words have very little effect on the prejudices of an Englishman.

Nothing would do but the engine must have a pump. So they put an eccentric on the projecting end of the shaft, and planted a single-acting pump under it, which was connected with the boiler by fully 60 ft. of 1 in. pipe, with four elbows, and no air chamber. That pump could be heard throughout the building, and while it remained afforded a permanent job to a machinist, to keep it in order and on its foundation. They soon removed it. It was several years after that before the independent steam pump became known in England.

The engine ran successfully at its new speed, but the beauty of its diagrams was gone. The speed was too rapid for the port areas, and in addition to this the owners concluded that a 2½ in. steam pipe was large enough, although quite long and crooked. However, the engine always ran cool, and did its work with ease, and they were satisfied.

The foregoing is, so far as I know, the first chapter in the history of high speed engineering, in its application to stationary engines.

I now ask your attention to some of the principles involved in the construction of high speed engines, a subject to which my first lecture may be regarded as introductory.*

The high speed engine has a fascination for the engineering mind, which is readily accounted for. The steam engine itself, irrespective of its speed, presents a pretty full compendium of applied mechanics. It involves the whole science of statics and dynamics, all the laws of force and motion and heat, and all the principles of mechanical construction. It presents the strongest contrasts. Some of its parts should maintain incessant motion, other parts absolute repose. In some of its parts weight, and in other parts absence of weight, is the great requirement. Some of its parts should maintain the highest, and other parts should maintain the lowest, attainable temperature.

Now the high speed engine is the steam engine intensified. High speed is the great revealer. Every

* SCIENTIFIC AMERICAN SUPPLEMENT, March 6 and 13, 1886.

defect in design or construction, every untruth, every departure from sound principles, all imperfections, which in a slow moving engine might never be suspected, in a high speed engine array themselves in plain sight, and imperatively demand attention.

High speed compels the designer to realize the fact, that he is dealing not alone with visible and material things, but always and primarily with those changeless realities which can only be the subjects of mental apprehension. These constitute mechanical science, to the study of which this and kindred institutions are chiefly devoted, and thorough familiarity with which alone enables the engineer to design successfully machinery of any kind whatever.

The early designers of steam engines had for their models only architectural forms. These they naturally copied; regarding as elegant what engineers of the present day, with a better knowledge of the fitness which true beauty can never violate, look upon as absurd.

Sir Joseph Whitworth was the first innovator on this long prevalent fashion. Although his designs were confined to machine tools, the principles on which they were based found after a while their application to the steam engine. "Let no man," said he, "show me a mechanical form for which he cannot give me a mechanical reason."

A prominent Pittsburg engine builder proceeded on a different principle: "Our designs," he once told me, "are the growth of experience. We make them at first as well as we know how, and when any part breaks we make it stronger."

I was not surprised to hear from this engineer a very unfavorable opinion of high speed. "We had," said he, "a customer who would have a small engine to run at 200 revolutions per minute; so we made it for him. No pains were spared on it. It was as good an engine as money could buy. At first it seemed to run pretty well; but after a while something broke, and directly afterward something else. One accident followed another, and we kept repairing it; but it was not very long, before it all came in pieces together, something like the deacon's 'One Hoss Shay.'" Now it is quite probable that, in the design of that engine, every principle that must be observed in the construction of high speed engines had been violated. The result makes it, in fact, necessary to believe, that there was not a solitary part or feature of that engine which was not different from what it ought to have been. Of course, however, the builder could never see its faults.

Let no one account himself a steam engineer until he has become able, habitually, to look within the material forms, and see in their reality the forces and stresses which are developed in the running of the steam engine at any speed whatever. Then only will he be able to make such disposition of material as shall remove his work entirely out of the region where a break down from weakness or imperfect action is possible.

The leading constructive requirements of a high speed engine are:

1st. Simplicity of design;

2d. Directness in the application of force;

3d. Ability to resist perfectly all stresses, both direct and indirect; and,

4th. Ample extent, and truth of form, in all wearing surfaces.

The horizontal is the form of engine which enables these conditions to be most completely met.

For a long time after the first introduction of the steam engine, its only form was the beam engine.

The first locomotive had a beam engine. But as higher pressures came to be used, the absurdity of transmitting power around three sides of a square, from the cylinder to the crank, and through a beam center perched on a scaffolding, and there working under a strain equal to twice the force transmitted, came, after multitudes of disasters had been suffered, gradually to dawn upon the minds of engineers; and to-day, except in the eastern United States, for use on paddle wheel steamboats, where also low pressures are used, the manufacture of beam engines has, I believe, entirely ceased. The horizontal engine has taken its place for stationary purposes.

The horizontal engine is of obscure origin, and for a long time was little accounted of. But in it lay all the possibilities of the future of the steam engine.

We naturally commence our review of the features of the high speed horizontal engine with

THE BED PLATE.

This is the back-bone of the engine, connecting the cylinder with the crank-shaft. The force of the steam on the piston, exerted alternately in opposite directions, is gathered in the center line of the cylinder, produced or extended to the crank. The theoretically perfect resistance to this force would be a resistance distributed equally all around this center line.

I have never but once seen this theoretical requirement realized in practice. In the trunk engines built 20 to 25 years ago by John Penn, for the British Navy, in which the diameter of the cylinder was from two to three times the stroke, and the distance between the cylinder and shaft was short, the pillow blocks on each side of the double cranks were formed in the apex of massive triangular frames, the bases of which were bolted to the cylinder flanges, which were extended in the form of a square, to receive them at the corners.

Such construction is not, however, ordinarily possible. The force of the steam must usually be resisted on one side of the center line. Then its tendency is to bend the bed-plate. In England, twenty years ago, I saw extreme illustrations of bad design in this respect. These were horizontal engines of moderate size, in which the bed plate *was* a plate indeed, being only three or four inches in depth and long and broad enough to accommodate the cylinder and pillow block and guides, which were set on it at such a height that the crank would revolve clear of its surface. The entire reliance, for keeping this plate from being broken in two by the stress along the center line, far above it, was on the bolts by which it was secured to the foundation.

I had left a better engine bed than that in common use at home. This was a long box, open, but provided with flanges, at top and bottom.

The sides and ends were from one foot to two feet deep, and so had considerable vertical rigidity. The crank in its revolution and the lower part of the cylinder were accommodated in the opening, and so the center line was brought not very far above the surface. The original of this bed-plate was evidently the two sticks of timber, with cross blocks at the ends and under the guides, which was the primitive horizontal engine bed, in this country, and with which a wooden connecting-rod or pitman was used.

The bed-plate now commonly employed in high speed engines is a deep box form casting, open at the bottom but closed at the top. It does not extend under the cylinder, but the end is formed into a hood, to which the cylinder is bolted. The cylinder is thus held with equal rigidity on all sides of its axis, and is free to expand and contract on changes of temperature. The center line can also be brought down to, or even below, the surface of the bed. Thus the engine is sufficiently self-contained in the vertical plane. The bed cannot yield at all in the vertical direction under the stress on the center line, nor under the pressure on the guides produced by the angular vibration of the connecting rod.

The most serious difficulty, of a purely constructive nature, is involved in the very common use of the single or overhanging crank. The force of the steam applied to this crank, being wholly on one side of the main bearing, tends also to deflect the bed plate horizontally. In order to resist this stress, the breadth of the bed plate is made at the crank end equal to the length of the main bearing, and this width gradually increases toward the cylinder.

The box form of bed is not capable of vibration or tremor, and constructed in the manner just described, at any speed of revolution, and under any pressure of steam, it is as quiet as if the engine were at rest.

THE CRANK AND SHAFT.

The single or overhanging crank is not a correct thing mechanically, but it is an exceedingly convenient thing, as well as economical in construction, and we must do the best we can to get rid of its mechanical defects. The force of the steam, applied to the crank projecting on one side of the main bearing, tends, as just mentioned, to deflect the bed. It tends still more strongly to deflect the shaft. When the piston is at either extreme of its stroke, and the connecting rod and crank are in the same line, on the line of centers, the pressure of steam admitted to the cylinder is exerted wholly to bend the shaft, and not at all to rotate it. At two points in every revolution the crank must receive the impact of the steam in this manner. For this reason, the main shafts of engines need to be made much larger than lines of shafting which transmit the same amount of power.

But we find that everything will bend. This model will exhibit the nature of this deflection of an engine shaft. The operation of the model is shown in Figs. 1 and 2. The action is best exhibited by employing, to

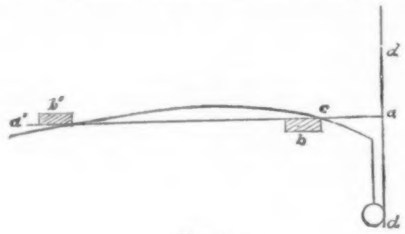


FIG. 1.

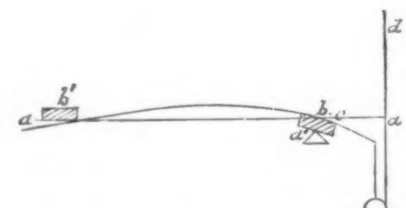


FIG. 2.

represent the shaft, a lath, which bends quite easily. The line, $a\ a'$, represents the position of this lath at rest, and $b\ b'$ represent supports on opposite sides of this lath, in places corresponding to the main and outer bearings of an engine shaft. The weight, d, being suspended from the end of the lath, the latter is deflected into the curve shown, over the extreme point, c, of the main bearing, b, as fulcrum. If the bearing, b, is not itself firmly supported out to the point c, then it also turns upon its point of support, which is represented in Fig. 2 by the triangle d', and the length of the lever at the end of which the weight, d, is attached becomes proportionately increased.

It is evident from this illustration that the end of the main bearing, c, ought to present an entirely firm support to the shaft at that point, and that the overhang, $c\ a$, ought to be as short as possible, and also that the shorter the distance between the main bearing and the outer bearing the better.

These principles of construction are observed in the best forms of stationary engines. In these the overhang of the crank has been reduced so much, and the support of the shaft in the horizontal direction has been made so firm, that practically the shaft suffers no deflection, and this difficulty from the use of the overhanging crank has disappeared.

In high speed engines, the thrust of the steam on the crank, as the latter passes each dead point on the line of centers, is also greatly lessened by the intervening inertia of the piston and rod, crosshead and connecting rod, which are termed, collectively, the reciprocating parts of the engine. It is obvious that the force of the steam must first be exerted to put these parts in motion, before any dynamical energy can be transmitted through them. At the commencement of each stroke these parts are at rest. The crank end of the connecting rod has then, indeed, a vertical motion, but in the horizontal direction it also, as well as the piston, is at rest. The vertical vibration of the connecting rod is an additional motion superadded upon its horizontal motion, and not affecting the problem we are now considering. We will therefore disregard it, and suppose the connecting rod to be moving in a horizontal plane, the same as the piston. From a state of rest at the commencement of the stroke, these parts have motion imparted to them at such a rate that at the middle of the stroke they are moving with a velocity equal to that of the crank pin in its circular path, and then this motion is lost as rapidly as it had been gained, so that at the end of the stroke they are at rest again. This alternate acceleration and retardation of their motion goes on perpetually.

It has been found that the accelerating force is greatest on the very center, where the motion of these parts from a state of rest begins, and that from this point it diminishes uniformly as the piston advances, until, at the mid stroke, when full velocity has been attained, it ceases altogether, and retardation begins, insensibly, just as acceleration had ceased. The retardation increases in the same uniform ratio in which the acceleration had diminished, and reaches its maximum at the very end of the stroke. The piston is most powerfully retarded at the point at which it is finally brought to rest.

This acceleration and subsequent retardation during a single stroke are represented by the triangles in Fig. 3. These represent the gradual diminution of the

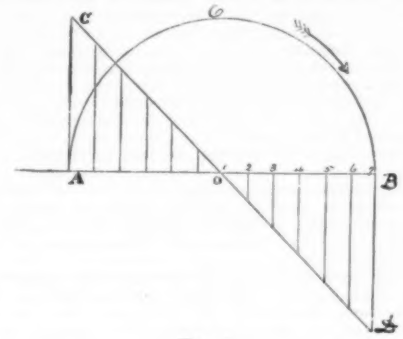


FIG. 3.

accelerating force, the insensible change from acceleration to retardation, and then the steady increase of the retarding force. In this figure, let the line, A B, represent the line of centers, or the line of motion of the reciprocating parts, and let the half circle, A E B, be drawn equal to the half circle of revolution of the crank, when A B will represent the stroke of the piston.

Let the perpendicular, A C, be drawn to represent the initial accelerating force which needs to be exerted to put the reciprocating parts in motion. Then from the point, C, draw the diagonal line, C D, bisecting the line A B at O. Then ordinates erected on the center line, A B, and terminating on the diagonal, C D, will represent at every point in the piston's stroke the force, first of acceleration and afterward of retardation, required at that point to cause the piston to keep up with the motion of the crank, without exerting any pressure upon the latter. The line, A C, may be taken of any length whatever. In this figure it is taken equal to A O, or the length of the crank. This will exhibit to us a very interesting relation between the path of the piston and the path of the crank, which we will presently observe in comparing this figure with Fig. 4.

We have thus seen the insensible manner in which, at the middle of every stroke, acceleration passes into retardation, at the vanishing point of each. We have now to observe how, on the other hand, retardation passes into acceleration. This transition is even more interesting than the former. It requires pretty close observation to perceive it. The effort is, however, magnificently rewarded. I will do the best I can, by way of description, to help you.

It is evident that at the end of each stroke retardation at its maximum must pass into acceleration in the reverse direction at its maximum. This transition is illustrated in Fig. 4. This figure represents the last

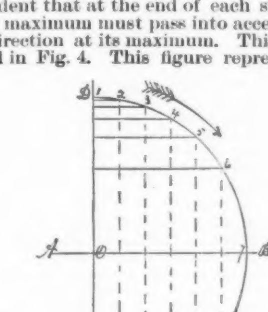


FIG. 4.

half of the forward stroke and the first half of the backward stroke. Let A B, as before, represent the line of the piston's motion, and let O B equal the half stroke of the piston, or the length of the crank. If now from the vertical line, E D, we draw horizontal ordinates to the circle, D B E, at points corresponding with the points in the path of the piston from which the ordinates were drawn in Fig. 3, the length of the two will in each case be the same. The ordinates which represent the acceleration and retardation, if drawn from the path of the piston, terminate on a diagonal line; if drawn from the path of the crank they terminate on the vertical line passing through the center. They will be identified in the two figures by corresponding numbers. In Fig. 4 each one is seen to be the cosine of the angle which the crank, when at that point in its path, forms with the line of centers.

Let now the crank have arrived at the point, D, Fig. 4. The piston is then at the point, O, Fig. 3, and the resistance of the crank is commencing insensibly to retard its motion. The resistance of the crank becomes greater and greater as the direction of its motion departs more and more from that of the pis-

ton's motion, and becomes greatest at the point, B, where its motion has become at right angles with that of the piston, and where the pressure of the crank upon the latter finally brings it to rest. Now, suppose no steam to be admitted to the cylinder, what takes place? Why the pressure of the crank upon the piston, *continuing in the same direction*, as the crank continues its revolution, imparts motion to the piston in the reverse direction. A careful study of this diagram will enable you to see clearly how it is that retardation of the motion of a piston controlled by a crank passes, at its maximum, insensibly, into acceleration in the reverse direction, at *its* maximum, and, as I have said already, the beauty of the sight will reward any amount of effort made to obtain it.

But I have only begun to speak of the attractions which this subject presents. The next is found in the *nature* of the accelerating force, at its maximum, at the commencement of the stroke. This force is, at this point, identical with the centrifugal force which the reciprocating parts would exert if they were revolving with the crank. How do we know this? You will recollect that in my former lecture I showed that centrifugal force was the inertia of matter, that it was the resistance which a revolving body opposed to being deflected from a straight line of motion, that the direction of the deflection was to the center, and its amount was the versed sine of the angle. Well, in this case also, at this point, the motion imparted to the reciprocating parts is directly to the center, and its amount is the versed sine of the angle, precisely as if they were revolving with the crank. So the amount of their inertia or resistance is identical with centrifugal force. The determination of the nature of this resistance makes it easy to ascertain its amount. We have only to use the formula for centrifugal force, with which we are already familiar.

$R^2 l n$ gives this resistance, and so the force required to overcome it, in terms of the weight of these parts. This product multiplied by the weight, and divided by the area of the piston in square inches, gives the pressure of steam per square inch which is necessary to be interposed, in order to relieve the crank from the labor of putting the piston in motion on the dead center.

The full formula thus becomes:

$$P = \frac{R^2 l n \times W}{a}$$

P multiplied by the cosine of the angle gives the accelerating or retarding pressure for every angular position of the crank.

At slow speeds the amount of accelerating force required is trifling. Thus in an engine of 5 feet stroke, making 40 revolutions per minute, we have $40^2 \times 2{\cdot}5 \times 0{\cdot}000341 = 1{\cdot}364$. Now let the weight of the reciprocating parts be equal to a pressure of 4 pounds on each one square inch of piston area, and we have required a steam pressure of $1{\cdot}364 \times 4 = 5{\cdot}456$ pounds on the square inch, which is not worth considering. But let us look at the other extreme. Suppose an engine of one foot stroke, making 600 revolutions per minute. Now we have $600^2 \times 0{\cdot}5 \times 0{\cdot}000341 = 61{\cdot}38$ times the force of gravity, and if the reciprocating parts have only a weight of two pounds for each one square inch of piston area, the initial accelerating and final retarding force which must be furnished, either by the steam or from the crank, is equal to 122·76 pounds per square inch of piston. We discover that this action is something to which, at high speed, it is important that we should give careful attention.

By the judicious employment of this force which lies in the inertia of the reciprocating parts of the engine, we are able to make it serve a very useful purpose. Variable expansion engines show on their diagrams extreme differences of pressure in the cylinder at the opposite ends of every stroke. This pressure is the entire boiler pressure at the commencement, and often nothing at all, sometimes even a negative pressure, at the termination. Thus the shaft is rotated and machinery driven apparently by a succession of violent punches, instead of a uniformly applied force. In slow speed engines of this character this is the very action that takes place. In high speed engines, however, we are able to absorb as much as we please of the energy of the steam in the reciprocating parts at the commencement of the stroke. This force is given out by them to the crank during the latter part of the stroke, and thus while the crank and shaft are relieved from severe pressures, the irregularities in the application of the force of the steam are compensated for in an admirable manner.

This is illustrated in Fig. 5. In this figure let the

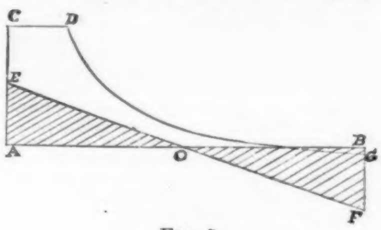


FIG. 5.

line, A B, represent the stroke of the piston and also the pressure of the atmosphere. Let A C represent an initial pressure of 60 pounds on the square inch, and D the point of cut-off, at one-sixth of the stroke. Then the expansion curve, D G, will fall below the atmosphere at the end of the stroke, as shown. Now let the weight and velocity of the reciprocating parts be such, that an initial accelerating force equal to 30 pounds on the square inch of piston area is required to put them in motion. Then the triangle, E O A, will represent the force of the steam absorbed by these parts during the first half of the stroke, and the equal triangle, B O F, will represent the force which their momentum exerts on the crank, in aid of the steam pressure, during the latter half of the stroke. The pressure on the crank throughout the stroke will be shown by the figure, E C D G F. It is an interesting feature of this diagram that, excepting a slight excess at D, it shows the pressure on the crank to be greatest where, on account of its angular position, the rotative effect of this pressure is least, and to be least at the middle of the stroke, where the full pressure is realized in rotative effect. When high presures are employed, as it is the tendency now to do, and as unquestionably will by and by be commonly done, it is evident that the designers of high speed engines will have a decided advantage in being able in this way to adapt their engines to run smoothly under these pressures.

In performing this function, of equalizing the pressures on the crank, and especially the rotative effect produced, through the stroke, and so equalizing the motion, the reciprocating parts of the engine act precisely in the manner of a fly wheel, first by their inertia absorbing the excessive force of the steam, and then, by their momentum, giving out this force to aid the failing steam. They have, however, an advantage over the fly-wheel, which is worthy of consideration. They alternately absorb and impart a force equal to their entire momentum, and they do this without any change taking place in the rotative speed of the shaft and wheel. The fly-wheel, on the contrary, absorbs and imparts forces which bear only small relation to its entire momentum, and this action takes place only as a consequence of changes in its rotative speed. The fly-wheel can absorb power only by increasing its speed, and impart it only by diminishing its speed. It is an imperfect regulator of motion, its regulating power depending wholly on its irregularities. The demonstration is a very neat one, that no engine can revolve with exact uniformity of motion; for, if it did so, then the fly-wheel would cease to act, and could be dispensed with. But this can never be done. One is surprised, however, to observe how small a fly-wheel is required to maintain steady motion in high speed engines until he reflects that the regulating power of any given wheel increases as the square of the number of revolutions, and also that in the case of high-speed engines the forces to be compensated by the fly-wheel in moving through a given distance are less in the same degree in which the size of the engine is smaller.

BALANCING.

In high speed engines the reciprocating parts must be, at least partially, balanced. The philosophy of balancing is very simple. When steam is admitted to a cylinder, it exerts its expansive force equally in all directions. This is the same on the cylinder head to move the whole engine in one direction that it is on the piston to move that in the opposite direction. The piston generally moves instead of the engine, because it is moved more easily than the engine.

So far as the force of steam is exerted on the crank, it does not tend to produce any disturbance of the equilibrium or stability of the engine; the pressure on the main bearing in the one direction is the same as that on the cylinder head in the other direction. But that portion of the force of the steam which is required to put the reciprocating parts in motion is wholly expended in doing this work, and does not reach the crank. These parts are shot out from the cylinder, or from their position in the cylinder, precisely as a cannon ball is shot out of a cannon, and the engine suffers the same recoil that the cannon does, and for the same reason. Action and reaction are equal and opposite. At high speeds, this recoil becomes strong enough to overcome the inertia of the engine and foundation, and sometimes of the building which contains them. This excess at least must be prevented. It can be prevented in only one way, which is by providing an equal or sufficient force acting in the opposite direction.

There are two essentially different methods of balancing the reciprocating parts of horizontal engines. The first of these consists in providing opposite forces acting along the same center line. Two cylinders facing each other on opposite sides of a crank, with their reciprocating parts so connected as to approach and recede from each other on alternate strokes, meet this requirement. In this construction the cranks, and the vertical vibrations of the connecting rods, are also opposite to each other, so that, if the weights of the moving parts are the same in each engine, the forces developed will be in equilibrium, not only in the horizontal direction, but in the vertical direction also.

The Wells Balanced Engine is constructed on this principle, only differing from the construction above described, in having two pistons moving to and from each other in one cylinder. If in making a steam engine the only purpose was to produce a machine running in equilibrium, this would be a perfect engine.

The other method and the one commonly employed, of balancing the reciprocating parts, in the degree found necessary, is by means of a revolving weight set opposite to the crank. The manner in which a revolving body acts to balance a reciprocating body presents a subject of much interest. I will endeavor briefly to explain it.

The centrifugal force exerted by a revolving body may, like any other force, be resolved into its rectangular components. Let us suppose the path of the crank, and which is also the path of the counterweight revolving opposite to the crank, to be bisected by vertical and horizontal planes, intersecting each other at the center of the shaft, and let us inquire about the horizontal and vertical components of the centrifugal force exerted by the counterweight.

In Fig. 6, let the circle be the path of the crank and of the counterweight, and let the line, AB, represent the horizontal plane and the line, DH, represent the vertical plane bisecting this path. Let the counterweight be supposed to have arrived at any point in its path, as for example, at the point C, and let the radius OC be taken to represent the amount of its centrifugal force, exerted in the radial direction OC. Then the vertical line, CE, will represent the vertical component, and the horizontal line, CL, will represent the horizontal component of this force. These lines represent the forces which, exerted in the directions, CE and CL, would together be in equilibrium with the centrifugal force, OC. But CE is the sine, and CL = EO the cosine, of the angle AOC.

Again, let the counterweight be supposed to have arrived at the point F. Then FG is the vertical component, and FD is the horizontal component of the same radial force OF. But FG is the sine, and FD = GO the cosine of the angle BOF. So we see that, in every position of the crank, the cosine of the angle which the crank forms with the line of centers, AB, represents the horizontal component of the centrifugal force exerted by the crank, and by the counterweight revolving opposite to the crank.

But we have already seen, in Fig. 3, that the cosine of this angle represents also, at every point in the revolution of the crank, the force necessary to be exerted on the piston at that point, in order to impart their velocity to the reciprocating parts of the engine, or which these parts in turn exert on the crank in aid of the steam pressure. Therefore, after the counterweight has balanced the crank itself, the horizontal component of its remaining weight becomes effective to balance both the inertia and the momentum of the reciprocating parts of the engine in the plane of their motion. The forces are opposite, and we may make them as nearly equal as we please.

It will reward us to go a little deeper into the acceleration of the piston's motion, and the balancing, in this way, of the force required to produce this acceleration. The relation between the versed sine and the cosine of an angle will explain it all. If we disregard the effect of the angular vibration of the connecting-rod on the motion of the piston, to which I do not intend to allude, and conceive the connecting-rod to be of infinite length, then the motion of the piston will always be equal to the versed sine of the angle which the crank forms with the line of centers, as AE in Fig. 6.

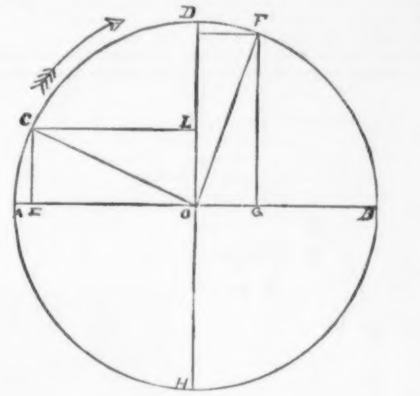


FIG. 6.

This is the motion of the piston. How do we find the acceleration of this motion? In the following way: The versed sine of any given angle gives the total motion of the piston from the commencement of the stroke, as, for example, AE, Fig. 6, represents the total motion of the piston while the crank is traversing the arc AC. Now, the difference between the versed sine for any degree and that for the next degree gives the motion of the piston while the crank was moving through the last degree. In this way, by getting the differences of the versed sines, we obtain the motion of the piston while the crank is traversing each separate degree.

Now, during the first 90°, or while the crank is moving from A to D, Fig. 6, we find that the piston moves further during each degree than it did during the preceding one. This increase in the motion of the piston during each successive degree measures the acceleration of its motion, and so the power required during each degree to impart it. Now, these second differences are represented by the vertical ordinates in Fig. 3, and by the cosines of the angles in Fig. 4. The second differences of the versed sines vary directly as the cosines. The reason why this is so I leave for you to demonstrate for yourselves. Upon this interesting relation this action depends. When you have demonstrated this relation, then you will have proved the efficiency of the revolving counterweight for its purpose.

The center of gravity of the counterweight may be nearer or farther from the center of the shaft than the end of the crank or center of the crank-pin. This makes no difference in its action, only the efficiency of a given weight varies directly as its distance from the center.

The amount of the counterweight, referred to the crank, or its efficiency to balance the reciprocating parts of the engine, may be ascertained as follows: After the crank with counterweight attached is on the shaft, and these parts of the engine are completed, lay the shaft on two parallel planes, one under each bearing, on which it will roll freely. Hang weight on the crank-pin until the crank is brought to the horizontal line. This will be equal to the portion of the counterweight available for balancing the reciprocating parts. The error from rolling friction is eliminated by adding to the weight until the crank falls below the horizontal plane, and then removing weight until it rises in the same degree above the horizontal plane. Half of the weight so removed added to that remaining is the exact measure of the counterweight.

I wish to observe here that I have never discovered any purpose to be served by balancing, except that of keeping the engine still. More counterweight than is needed for this purpose is unnecessary. This in stationary engines rarely needs to be more than one-half the weight of the reciprocating parts.

The counterweight has also a vertical action, which is represented by the sine of the angle which the crank forms with the horizontal, or the cosine of the angle which it forms with the vertical plane. This vertical component of the centrifugal force of the counterweight in horizontal engines we have not yet paid attention to. The truth is, this vertical stress does not need any attention in ordinary cases. It is in some degree counteracted by the opposite vibration of the connecting-rod. The portion which remains unbalanced cannot exert any disturbing or other injurious effect. The engine cannot be put in vibration in the vertical direction; this is the plane of greatest resistance. In fact, unless there be elasticity in the foundation, the vertical action of the counterweight is resisted by the entire mass of the earth. In the upward direction, also, this force would have to be sufficient to lift the shaft, crank, and fly-wheel from the bearing, before it could make itself felt. So, practically, it is not found necessary to pay any regard to it.

It has been amusing to read the demonstrations of mathematicians, who overlook all these considerations, by which they prove that the vertical action of the

counterweight in stationary horizontal engines must be compensated for at high speed, and who propose to disfigure the engine by a great increase in the size of the crank end of the connecting-rod for this purpose.

In locomotives, the case is quite different. There the counterweight at every revolution strikes a blow on the rails, and should therefore be used as sparingly as possible.

Like all other good things, the action of the reciprocating parts of an engine, as a reciprocating fly-wheel, can easily be overdone, and the danger is, in short-stroke high-speed engines, that it will be overdone. Generally speaking, the best construction will be found, as already stated, to design the reciprocating parts so that they will absorb, at the commencement of each stroke, about one-half of the pressure of the steam, whatever that may be, and more than this rather than less, and then to provide counterweight to balance about one-half the weight of these parts. It will be found that, at very high speeds, lightness in the reciprocating parts will need to be studied, rather than weight. It is believed that sufficient instruction has now been given to enable the designer to meet any case that may arise.

The motion of a piston controlled by a crank may properly be termed revolution in a straight line. The insensible manner in which the reciprocation of the piston becomes transformed, through the medium of the connecting-rod, into the revolution of the crank is

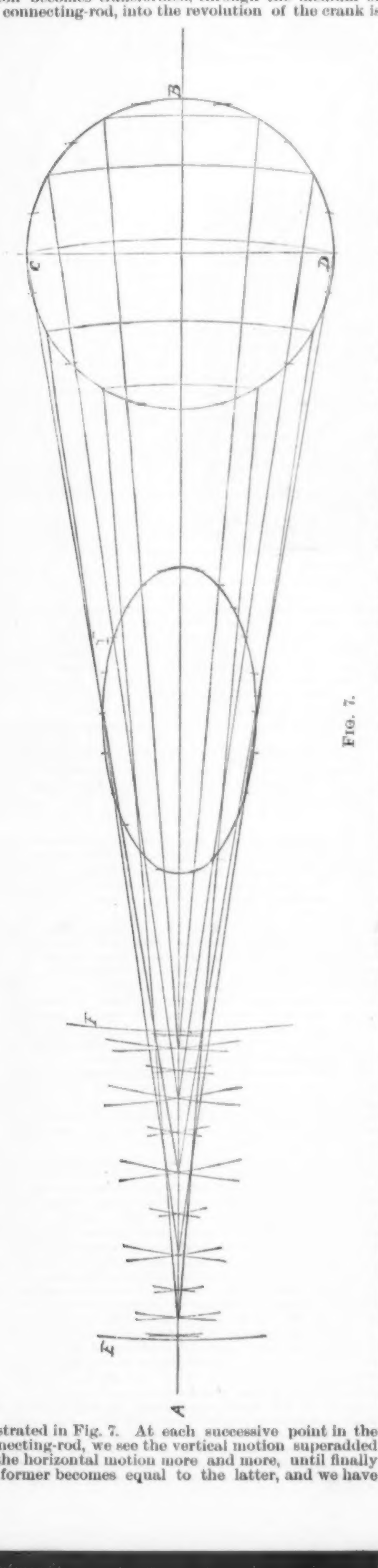


Fig. 7.

illustrated in Fig. 7. At each successive point in the connecting-rod, we see the vertical motion superadded on the horizontal motion more and more, until finally the former becomes equal to the latter, and we have revolution in a circle. So, reversing the observation, as we pass from the crank back to the crosshead, we see the vertical motion diminishing gradually, until it disappears altogether. It should be observed that the figure described by any intermediate point of the connecting-rod, as it gradually contracts from a circle to a line, is not anywhere an ellipse, but is an ovate figure, the larger end of which is nearest the crank. This will be distinctly seen if drawn on a large scale.

TRUTH OF CONSTRUCTION.

From this brief sketch of the general principles to be observed in designing high-speed engines, we pass to another subject, which is of scarcely less importance, namely, truth of construction, at which time permits only a rapid glance. This is a matter over which the designer has generally little control. It lies within the province of the constructor. Yet it is a subject with which the designer should himself be thoroughly familiar. He should acquaint himself with all constructive methods, and should be capable of designing those which will be most certain to insure the result, in truth of construction, and of judging of the value of those which he observes in use. His standard should be high. The more rapid the speed at which an engine is to be run, the greater becomes the importance of truth. Man demands of a steam engine what his Maker demands of him, namely, "truth in the inward parts."

The importance of truth of construction becomes apparent when it is considered that, supposing the forces developed to have been thoroughly studied, and the requirements in the design to have been fully observed, then, if entire truth of construction is achieved and maintained, it is immaterial how rapidly our engine is run. It is equally safe at all speeds. But the difference is as wide as the world between right and nearly right. Nearly right means continual trouble; absolutely right means entire exemption from trouble. It is easy to approximate to truth, and there is a constant pressure on the engineer to be satisfied with such approximation. The absolute realization of truth is a matter of difficulty. It demands perfect methods, and watchful oversight and rigid inspection. Relaxation of vigilance is always followed by deterioration of work.

I will enumerate a few of the principal points in which truth is essential. These are:

That the cylinder be in line with the guides.

That the journals be cylindrical.

That the shaft be at right angles with the motion of the piston.

That the guides be true planes, or true segments of a cylinder; and lastly:

That the crank-pin be cylindrical, and parallel with the shaft.

The setting of the crank-pin so that it shall be parallel with the shaft, and testing for such parallelism, and correcting the error, however minute, is so important, indeed so essential, to the perfect running of a high speed engine, that a brief description of the operation will be given. This will illustrate also the accuracy everywhere demanded and attainable.

The operations of boring and turning the crank disk, and of shrinking or forcing and keying it on the shaft, are liable to change its form. The operation of boring the eye for the crank-pin is therefore left until the last. This operation is, or should be, performed in a machine, in which the feed motion of the boring bar is parallel with the line connecting centers between which the shaft is held. The pin is finished by grinding between dead centers with a wheel; both the wearing surface and the shank of the pin being ground to insure their truth relatively to each other. The pin is then set in the eye by hydraulic or screw pressure, and riveted. All the means for attaining truth of direction having been employed, the result might be supposed to be perfect. A test will, however, always show that it is not so. This test is made by means of a spirit level. A ground bubble is employed, which will move with precision at least one-sixteenth of an inch on a variation of direction of 0·001 of an inch in a length of one foot. The shaft is laid in an approximately level position in its bearings, or in V blocks under its journals. The level is set on an inverted V block on the crank-pin. A cross level is also employed to insure that the testing level shall always be applied in the same position—on top of the crank-pin. The crank is then turned successively to four positions, approximately at right angles with each other. Thus the level is applied to four sides of the pin. If the bubble maintains the same position at each of these applications, the pin is parallel with the shaft. It never does so on the first trial. Though the eye be bored quite truly, and great pressure be required to set the pin, still the operation of riveting will cast the pin more or less. This is proved by the fact that additional riveting, at the right points as indicated, will correct the error. That is the way in which this is done.

The tendency in high-speed engineering is toward shorter strokes. It is realized that length means limberness. Especially when high pressures are used, rigidity in the moving parts as well as in the stationary parts of the engine becomes highly important. It used to be thought by makers of stationary engines that there was a certain fit and proper proportion between the bore of the cylinder and the stroke, which ought to be observed. The latter was generally made three times the former. Following this rule, I made the two little engines which I have described, the one 6 in. × 18 in., the other 8 in. × 24 in. This proportion met also the marked approval of builders of stationary engines in England. I saw, however, in the Exhibition of 1862, a great cylinder, made by Mr. Penn for a vessel of the British Navy, of 120 in. diameter, the stroke being 40 inches. Here these proportions of three to one were reversed. The bore was three times the stroke. These proportions were rendered necessary by the limited space for the accommodation of a horizontal engine lying crosswise in the hold of a vessel, and having the shaft on the center over the keel. Engines so proportioned worked just as well as any others. In high speed engines the stroke now never exceeds twice the bore, and, especially in large engines, it is sometimes only equal to the bore. For great speed of revolution, the stroke may with advantage be made less than the bore.

I will conclude this brief presentation of what occur to me as the more prominent requirements in the design and construction of high-speed engines, by reference to the subject of areas of steam passages. These areas are governed by the velocity which it is proposed that the steam shall have in its passage into and out of the cylinder. It has been found that, through short and straight pipes, a difference of pressure of 1 lb. on the square inch will give to steam a velocity of about 200 feet per second. The best practice requires a velocity no greater than this for the entering steam, and of 130 feet per second for the exhaust, when the piston is moving at its mean speed. Thus the areas of the ports are determined wholly by the piston displacement per second. So, in a cylinder of given bore, the port areas are fixed by the speed of the piston, without regard to the length of the stroke. A given speed of piston requires the same port area, whether the stroke be long or short. In this single respect of the percentage which waste room in the ports adds to the length of the cylinder, the advantage is, therefore, with long-stroke engines.

For high-speed engines, the area of the steam pipes needs to be much greater than that of the ports. This is on account of the retardation which the steam suffers from surface friction in the pipes and at the bends. Often twice the port area is not too much in the pipe.

For engines which cut off early, and where the boilers are at a distance, it is found to be an excellent practice to employ a steam receiver of considerable size, placed close to the cylinder, in which the boiler pressure is nearly maintained through a comparatively small pipe, the flow of steam in this pipe being continuous, unaffected by the cut-off. In this receiver, also, by proper construction, water contained in the steam is precipitated, and may be trapped off, and dry steam taken over to the engine. In my own practice, this receiver has often proved extremely useful, sometimes essential to the results attained, both in power and in economy.

Note.—The attention of American engineers was first distinctly called to this source of loss by experiments conducted by Mr. Isherwood, in the year 1860, on the engine of the steamer Michigan, on Lake Erie. These experiments showed the proportion of the steam condensed, on entering the cylinder of the condensing engine experimented on, to vary from 10·71 per cent. when cutting off at eleven-twelfths of the stroke at 20·6 revolutions per minute to 42·11 per cent. when cutting off at one-sixth of the stroke at 11·17 revolutions per minute.

Since that time, the tendency has been to pay more and more regard to this loss, and to the means by which it may be diminished, and thus the theoretical gain from expansive working be more nearly realized.

On entering the cylinder, the steam loses a portion of its heat, this being imparted to the metal with which it comes in contact, to restore to this metal the heat of which the colder exhaust had just robbed it.

These differences of temperature are not always realized. Between 100 lb. gauge pressure and the atmospheric pressure this difference is about 125° F., and between the atmospheric pressure and a pressure of 1·25 in. of mercury, which vacuum is often maintained, the difference is about 125° F. more; the total being 70° F. more than the difference between the temperatures of ice and boiling water.

The effect of this on the steam may be observed by opening a steam cock on the steam chest and another on the cylinder. No one can witness without astonishment the change often to be seen from invisible steam blowing from the chest to snow-white steam issuing from the cylinder, the whiteness being due to minute particles of water diffused through the steam.

The amount of steam thus condensed in restoring the heat to the metal varies extremely in different cases. The conditions by which it is determined are the following:

First. The conducting power of the metal.

The absolute surface exposed to the entering steam must be heated and cooled instantly, so that its temperature shall always be the same as that of the steam in contact with it, however rapidly this temperature may change. The question is, How deeply into the body of the metal shall the changes of temperature penetrate? This penetration, other conditions being the same, depends on the conducting power of the metal. Practically, this condition is a constant one, since the same metal, cast iron, is universally employed for cylinders. It is, however, important to perceive clearly the nature of the action. This is such that in a cylinder of copper the loss of heat would be 60 per cent. greater, and in a cylinder of porcelain it would be only one forty-eighth as much, as in cast iron.

The conducting power of glass is probably about as low as that of porcelain, and this, together with the trifling pressure carried, involving but little difference between the boiler and the exhaust temperatures, accounts for the clearness of the steam in the engines sometimes shown in operation by glass blowers.

The low conducting power of porcelain has led to schemes for covering interior surfaces of cylinders and pistons with a protection of this material. The impossibility of producing any mixture of a mineral character having the same rate of expansion as cast iron has, however, compelled their abandonment.

The *second* condition determining the amount of steam condensed in the cylinder is the *extent of the surface* with which on entering it comes in contact. All these surfaces, in cylinder, piston, covers, ports, and valves, must be measured in estimating the amount of loss suffered in this way in any given engine.

The *third* condition is *time.*

It is obvious that, with metal of given conducting power, the depth to which these changes of temperature will penetrate must vary directly as the time.

By running pumping engines in the city of Providence at one revolution per minute, Mr. Corliss, although using superheated steam, once succeeded in condensing more than eleven-twelfths of the steam as it entered the cylinder. Indeed, it seems as if even more than this proportion of the steam was condensed, since the duty obtained by the combustion of 100 lb. of coal was only about 8,000,000 foot pounds, one-twelfth of ordinary good duty, and less than one-fifteenth of the wonderful duty obtained by Mr. Corliss in his subsequent engines; and the diagrams showed about one-half the pressure exerted to be due to re-evaporation in the cylinder after the cut-off. At each stroke, the condensation of the entering steam was as much as, at 60 revolutions per minute, it would be in sixty strokes,

and possibly more, because the large volume of water would cool the cylinder during the exhaust so much more than it could be cooled by a little water quickly evaporated.

The *fourth* condition is *the difference between the temperatures of the entering and exhaust steam.*

The rate of the alternate cooling and reheating of the metal varies directly as the difference of these temperatures. For example, if this difference is 100°, the condensing and re-evaporating action will go on with ten times the rapidity that it will do if the difference is 10°.

The *fifth* condition *is the presence of water.*

This is an important condition. It is water, and not dry steam, in contact with the internal surfaces that most rapidly imparts heat to, and abstracts it from, the metal. The subject can only be alluded to here. The condition is one which varies extremely in different cases.

Since time is an essential factor in determining this loss of heat in the cylinder, it would naturally be supposed that high-speed engines would show a decided gain in economy. If, for example, the speed of a given engine be doubled, and the ports are sufficient, so that it gives the same diagram of pressure as before, then it does twice as much work, and the weight of steam worked through the cylinder is twice as great. But the condensation and re-evaporation in a given time are not increased. Then the percentage of loss from this cause will be only one-half as great as before.

This expectation has not been realized. High-speed engines have not as yet shown a decided advantage in economy.

There are ample reasons for this disappointment. Sometimes the steam is condensed on its way to the cylinder, in a degree that renders economy hopeless. Generally, the waste room is excessive, and often the surfaces on which the condensing and re-evaporating action takes place are extensive. Sometimes these faults are combined. There is room yet for a high-speed engine in which these drawbacks to economy shall not exist. From such an engine the economic results properly due from high speed may reasonably be expected.

A WATCH WITHOUT HANDS.

THE Messrs. Schwob have recently brought a novelty into fashion, and that is a watch without hands. As a usual thing, it taxes the attention somewhat to

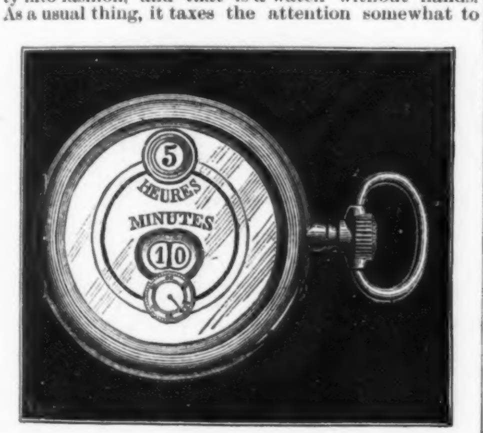


FIG. 1.—WATCH WITHOUT HANDS.

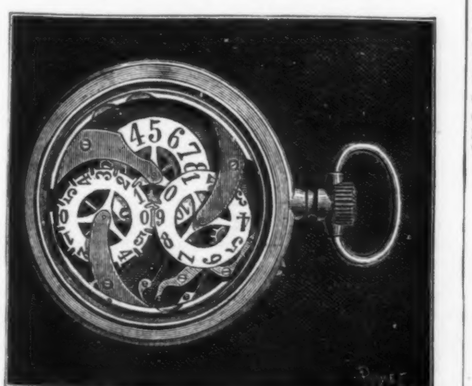


FIG. 2.—DETAILS OF THE MECHANISM.

read the time. In order that we may know what time it is to the minute, our eye must take in both hands at once, and clearly see each division of the face. Now this, it appears, is more difficult than we would at first sight be led to believe, for, out of ten persons put to the test, we found but four who read the minute accurately. As a general thing, we are deceived by at least a minute or a minute and a half. The handless watch overcomes this trouble. Its face, which has no divisions, is provided with two small apertures merely, one above the other. In the one above we read the hour, and in the one below, the minutes. There is no longer any hesitation possible, for the hour and minutes appear clearly in black upon a silver background; for example (see cut), 5 hours in the aperture above, and 10 minutes in the one below. The seconds are marked by a small seconds hand.

It is not difficult to guess the secret of this combination. The silver background upon which the hour is inscribed in black figures forms the surface of a disk (or small dial, if you please), whose circumference carries the twelve hours of the day. Only the surface of the disk and the figure are shown in the aperture. The disk revolves by one division every sixty minutes, and this pushes the succeeding figure under the aperture. Under the minute aperture there revolve in the same way two small tangential disks, of which we can see only a portion of the juxtaposed rims. The one to the right carries the minutes, and the one to the left the tens of minutes. The units figure changes every sixty seconds, and the figure of the tens every ten minutes. The successive and repeated appearance of the new figures under the apertures is not without interest to the curious. Briefly, this is a watch with ordinary wheelwork in which the intermediate teeth are wanting, and which gear every minute and hour only (Fig. 2). This contrivance, although it may doubtless possess some inconveniences from certain points of view, offers, on another hand, genuine advantages. It not only allows the reading to be done with accuracy, but also permits of estimating the time that separates each passing minute. There is not only an optical signal given, but also an acoustic one, since at every change of figure the ear perceives a slight sound; and so it becomes useless for one to examine his watch in order to measure a given interval of time. This is a feature of value to engineers, physicians, officers, travelers, and observers generally. The experimenter knows exactly when a minute begins and ends. The independent seconds hand does not give such a result.

So it seems to us that the handless watch is to render services that we could not ask of a costly chronometer even.

A WAGON WHEEL WITHOUT AXLE.

THE yearly exhibit of agricultural machines at the Palace of Industry usually furnishes its quota of new and interesting mechanical inventions. Among these, we shall cite two in particular which are peculiarly interesting, for they concern objects that did not appear to be capable of modification—we mean the ordinary wagon wheel and the trundle for moving goods about.

The new wheel, which was exhibited by Mr. Suc, and is shown in Figs. 1 and 2, entirely dispenses with axle, grease boxes, journals, axle boxes, etc. The part, A, of the wheel is permanently fixed to the frame of the wagon, which is moved forward through the rotary

FIG. 1.—WHEEL WITHOUT AXLE.

motion of the external felly, B, which forms a sort of circular rail around A, and rests upon the ground. It thus substitutes a rolling friction at the circumference for the sliding friction of journals in their boxes.

The principle of the wheel is as follows: If we place two grooved rails on the ground, and insert in the grooves a number of steel balls, T, that are held at equal distance apart in the apertures of a guide, C, and then place two grooved rails over the whole, in such a way that the groove shall embrace the balls, and if we then cause the two upper rails to slide over the lower ones (which remain stationary), the movement will be effected through the simple rotation of the balls. If, now, we curve the whole, we shall have a wheel in which the rail, A, will form the stationary felly, and

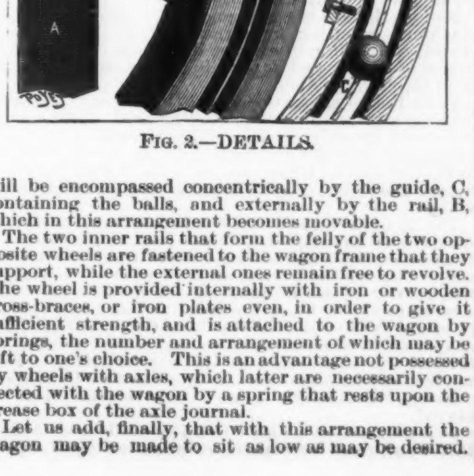


FIG. 2.—DETAILS.

will be encompassed concentrically by the guide, C, containing the balls, and externally by the rail, B, which in this arrangement becomes movable.

The two inner rails that form the felly of the two opposite wheels are fastened to the wagon frame that they support, while the external ones remain free to revolve. The wheel is provided internally with iron or wooden cross-braces, or iron plates even, in order to give it sufficient strength, and is attached to the wagon by springs, the number and arrangement of which may be left to one's choice. This is an advantage not possessed by wheels with axles, which latter are necessarily connected with the wagon by a spring that rests upon the grease box of the axle journal.

Let us add, finally, that with this arrangement the wagon may be made to sit as low as may be desired. The wheel may be applied to all kinds of vehicles, and thus, through the lowering of their bottom, give them a stability much greater than they would otherwise have. The bottom of the wagon may be brought close to the ground, and consequently permit aged or infirm persons to get into the vehicle without any trouble. Security against accident is in this way obtained, since the fall to be feared is, so to speak, *nil.*

Doubtless the drawback to the general application of this ingenious arrangement will be the complication of the felly, and especially the difficulty of preventing mud

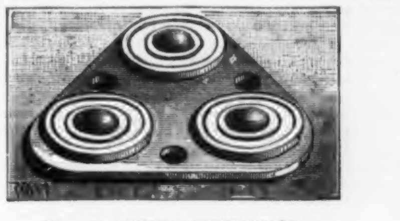


FIG. 3.—SUC'S TRUNDLE.

from accumulating in the grooves in rainy weather, when the streets are dirty. Mud and sand cannot help interfering with the rotation of the balls, and causing enormous friction.

It would be interesting at all events to have the results of some comparative experiments that would permit of estimating the tractive stress required by this style of wheel, as compared with that of the ordinary type, in streets paved with wood or stone or macadamized, or on roads in an ordinary state of repair.

As belonging to Mr. Suc's exhibit, we must also mention a new style of trundle for moving goods about. This is shown in Fig. 3. It consists of three balls, 2½ inches in diameter, whose centers are held in an unvarying position at the apices of an equilateral triangle. These balls move between two disks that are riveted to a piece of iron plate which connects the whole affair. They readily yield to the stress that is exerted upon them, whatever be its direction, since any two of them can always pivot around the third.

MARINE ENGINE CRANKS AND SHAFTS.

FLEXIBLE CRANK AND PROPELLER SHAFTING IN LIEU OF RIGID SHAFTING FOR MARINE PROPULSION.*

By Mr. J. F. HALL.

THE object of this paper is to direct the attention of members of this Institution to an improved method of constructing the crank and screw shafting of steam vessels, so as to enable them to escape the multitude of strains and contortions that such shafting has to undergo.

In April, 1884, I had the honor of reading before this Institution a paper on "Cast Steel as a Material for Crank-shafts, etc." That paper related entirely to material, and was at the time, and since, submitted to considerable criticism. I may say, however, that up to the present time, I have seen no just cause to alter in the slightest degree my opinions, as set forth at that time. On the contrary, I have had my then convictions intensified beyond all expectations; and if I dare enumerate the number and condition of broken forged shafts that have, since that paper was read, been brought under my notice, I should considerably astonish a number of my hearers.

I may add that, as far as I am aware, not one of the cast steel shafts mentioned in my previous paper, or of many others since made, has broken or failed through quality of material. I must admit, however, that I consider this due, in a certain extent, to good fortune, as there are many steamers that will break rigid shafts of any material, no matter if that material be twice as strong as anything yet made.

This brings me to the main point of the present paper, viz., to show that both crank and propeller shafts, quite as often as through defective material, fail through being unduly bent or strained in an irregular line of bearings, which get out of line with each other, when unequal wear takes place, and when the hull of the vessel slightly alters its shape through the action of the sea, climate, temperature, or unequal distribution of cargo. These evils are often intensified by the natural flexibility and springy nature of the hulls themselves, which the tendency of the age is to build too light.

To practical marine engineers there is no wonder that a shaft should fail when so bent in its bearings from any of the above causes, for it has to endure not only torsional strains, but it has to resist cross bending strains

* Paper read at the twenty-seventh session of the Institution of Naval Architects.—*Engineering.*

alternately at every revolution of a tensile and compressive nature on its outer skin, varying in intensity as the degree of flexure.

These strains, coupled with the great vibration they produce, distress and fatigue the material of which the shaft is composed till it becomes crystallized, and its molecular arrangement disorganized to such an extent that its vitality is exhausted, when its failure may be expected at any moment.

Sometimes, though rarely, the shaft, in conforming to the irregularities in its line of bearings, gives way at one or more of its couplings. This only happens, however, when the resistance to be bent offered by the body of the shaft is greater than the tensile resistance the bolts in the coupling are capable of offering, through being either numerically weak or too small in section. To say the least, such an event occurring is a great source of annoyance and expense, for if the bolts be made of hard and unyielding material, they are in danger of being pulled asunder.

Again, if they be made of suitable material to withstand such stresses without breaking, they will, by the continual stretching to which they will be subjected, become elongated in their shanks, thus fitting loosely through the coupling cheeses. In this latter case backlash will be set up, in consequence of which shocks will occur distressing in their effects to the whole propelling apparatus.

Also there will be a tendency to shear the bolts in two, as those who have to replace the same are able to testify by their ruffled feelings.

But more particularly liable to be fractured is the crank-shaft section itself, through causes other than defective material.

No doubt, there are many members of this Institution acquainted, and some personally, with vessels that have acquired the reputation of being notorious crank-shaft smashers. It is no uncommon event for some vessels to require a new shaft every one or two years, and in the majority of vessels, seven years is considered a good life for the shaft. In very few vessels is the fear of breakage in the shaft minimized to the extent that the fear of a boiler explosion is.

Alarming as this unsatisfactory state of things appears, of the pistons tending to bend it, is unable to oppose with equal resistance throughout its length any tendency of wear in the brasses.

Therefore unequal wear in the brasses is encouraged, as the frictional work they are submitted to, in supporting the shaft, is unequally distributed between them.

Then the bearings are apt and actually do get out of line forward and aftward, or both at once, with the tunnel bearings, through the straining of the hull, or the partial disarrangement of the foundation plate, plumber-block bearings, etc.

Add these facts to the unequal wear in the brasses, and you have the reason at once apparent why fracture takes place in the crank-pin or across the webs instead of in the fillets of the journals themselves, where the greatest legitimate strains should be centered.

It is obvious that when, for instance, in a two-throw shaft as illustrated in Fig. 16, the bearings of the after-crank have fallen (be it ever so slightly) below those of the crank on the forward side, and the tunnel bearings on the after side, the crank with the propeller shaft at that unsupported or partially unsupported point is liable to be, or actually is, bent by the efforts of the piston centered in that locality.

As a consequence, multiple, tensile, and compressive strains of great intensity will be localized in the crank-pin and across the webs, in the after-crank, where the bending effort of the piston is centered, and where owing to its peculiar symmetry of form the shaft naturally seeks relief when being overcome in its struggles to retain its true shape.

Again, bending stresses are localized, and an attempt to find vent in the after-crank when the propeller shaft is strained at an angle to the crank-shaft or when the after-crank, assisted by the propeller shafting, attempts to support the forward crank whose bearings have fallen.

As the forward crank is supported only on its after side when its bearings fail it, while the after-crank has supports aft and forward to support it when its bearings fail it, the shaft is more easily bent in the after-crank by the forward piston than it is by the after piston, as the shaft is not so well supported forward as aft.

and mechanically by yielding at certain points in its length to irregularities that may at one or more points occur in its line of bearings.

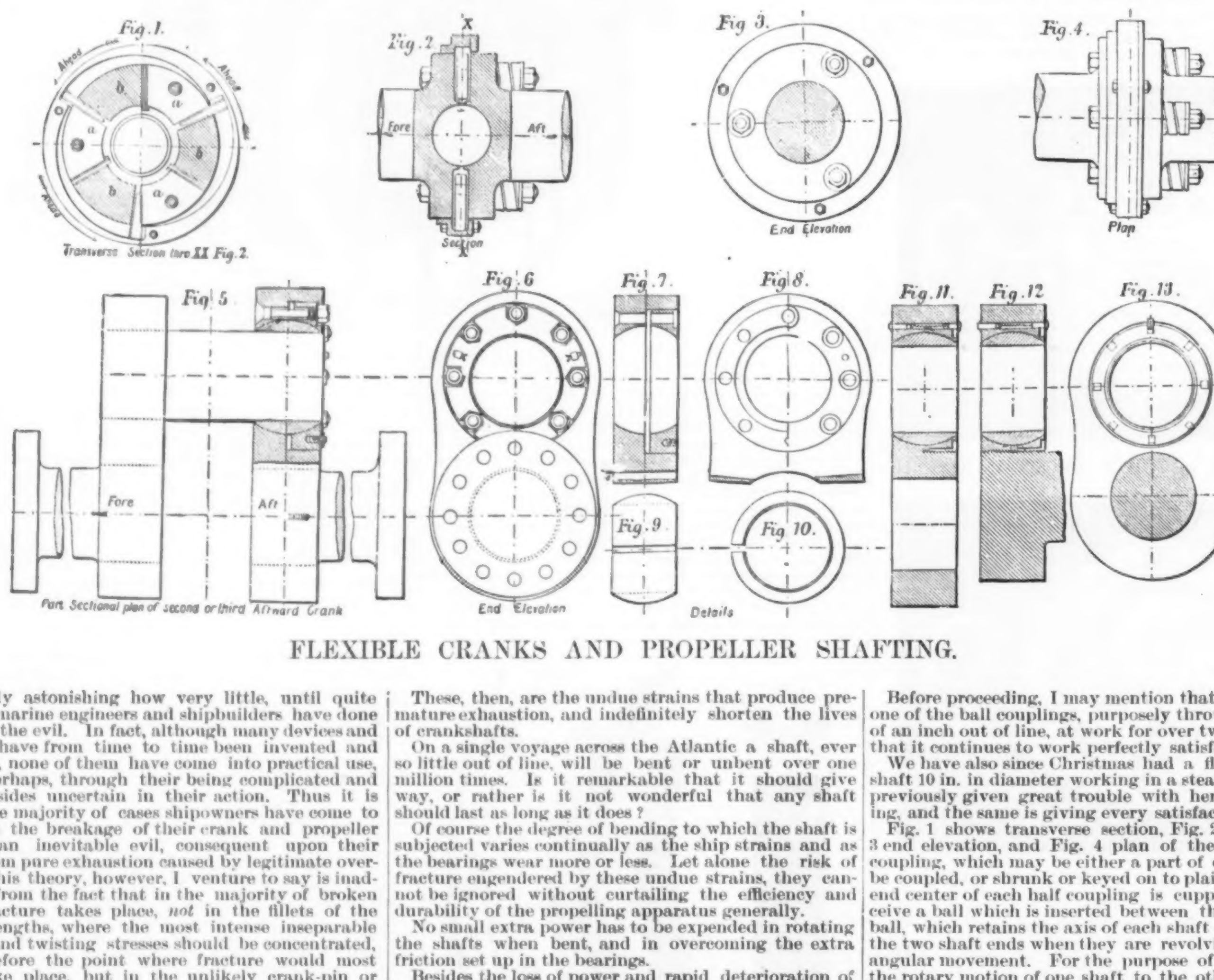
Some five or six years ago my firm, Messrs. William Jessop & Sons, Limited, of Sheffield, took up the manufacture of Thomas Turton's patent built-up crank-shaft, as illustrated in Fig. 21, and have, since that time, made a considerable number of them.

The chief feature of this crank, as originally claimed by the patentee, was the facility with which the crank-pin part could be replaced, and he hoped to have been able to do it even at sea.

Although this desirable faculty has not been realized to the extent wished for, it has in its very failure developed a virtue in the shaft that was not in the first instance claimed for it, viz., to allow itself to slightly bend, unbend, and even slightly twist in an irregular line of bearings without a tendency to break or do more than elongate or distort the bolts passing through the webs and holding the shaft together. It will be readily understood that this very action, although preventing the shaft itself from breaking, increases the difficulties of taking the bolts out and the shaft to pieces, but the loss of this advantage is more than recompensed for by the other.

It was this extraordinary development in the working of Turton's shaft that led me to investigate the causes thereof, and subsequently to take up the flexible ball coupling patented by Mr. Verity, although the same was at the time somewhat complicated and cumbersome. However, as two heads are better than one, we have, together, since then considerably simplified and reduced the coupling to what we think is a practical success.

It was during the study of this ball coupling or universal joint that it occurred to my mind that the proper place for at least a part of the flexibility was at the end of the crank-pin in the after web. This idea was no sooner thought of than it was rapidly developed, and so admirably worked out by Mr. Verity, that I have no hesitation in now submitting it, viz., the flexible crank-shaft, together with the flexible ball coupling, and how we propose to apply the same, for the consideration of the members of this Institution.



FLEXIBLE CRANKS AND PROPELLER SHAFTING.

it is really astonishing how very little, until quite recently, marine engineers and shipbuilders have done to rectify the evil. In fact, although many devices and methods have from time to time been invented and suggested, none of them have come into practical use, chiefly, perhaps, through their being complicated and costly, besides uncertain in their action. Thus it is that in the majority of cases shipowners have come to look upon the breakage of their crank and propeller shafts as an inevitable evil, consequent upon their failing from pure exhaustion caused by legitimate overwork. This theory, however, I venture to say is inadmissible, from the fact that in the majority of broken shafts fracture takes place, *not* in the fillets of the journal lengths, where the most intense inseparable bending and twisting stresses should be concentrated, and therefore the point where fracture would most likely take place, but in the unlikely crank-pin or across the webs, where by right no such great strains should exist.

This fact of itself should convince every shipowner that his shafts rarely break through pure overwork, but that there is something else radically amiss in their construction. The object of this paper is to point out what this something else is, and to show how to rectify it.

In a few words, then, this great evil which is so disastrous in its effects arises through the shaft revolving when bent or sprung into an irregular line of bearings. This defect is one that all crank-shafts with two or more throws are liable, more or less, to be troubled with.

In support of this theory every-day experience shows conclusively that no two bearings can be expected to wear equally one with the other, even when all conditions are supposed to be equal, unless it be by chance.

It cannot then be expected that the bearings of the respective cranks one with another or with those of the propeller shafting should wear equally, especially when it is considered that the conditions are unfavorable to lead us to expect such a desirable end, because the shaft, in its rigidity, being incapable of opposing with equal resistance forward and aftward the efforts

These, then, are the undue strains that produce premature exhaustion, and indefinitely shorten the lives of crankshafts.

On a single voyage across the Atlantic a shaft, ever so little out of line, will be bent or unbent over one million times. Is it remarkable that it should give way, or rather is it not wonderful that any shaft should last as long as it does?

Of course the degree of bending to which the shaft is subjected varies continually as the ship strains and as the bearings wear more or less. Let alone the risk of fracture engendered by these undue strains, they cannot be ignored without curtailing the efficiency and durability of the propelling apparatus generally.

No small extra power has to be expended in rotating the shafts when bent, and in overcoming the extra friction set up in the bearings.

Besides the loss of power and rapid deterioration of machinery resulting from these actions, heat is generated, which, if not exactly dangerous, is always a source of trouble and anxiety to the engineer, especially in the crank section.

From the foregoing remarks, I think it may be taken for granted that, under the existing mode of fitting up crank and propeller shafts, neither the naval architect nor marine engineer can control all the forces tending to bend or distort them; no, not even if they line up, renew, and adjust all the bearings at the end of every voyage.

The fact that a good steel shaft of the same torsional strength as an iron one, though considerably less in diameter, lasts a much longer time than the latter, shows that the thicker a shaft is of a given strength, the greater is the liability of fracture, because the stresses produced when the shaft is bent increase in intensity as the square of the diameter. Consequently, it appears to be certain that so long as we attempt to combat by brute strength the uncontrollable forces tending to fracture a shaft, so long shall we be beaten.

Hence, that which cannot be overcome must be eluded.

It is patent that a shaft, to successfully accomplish this want, must be capable of adapting itself freely

Before proceeding, I may mention that we have had one of the ball couplings, purposely thrown a quarter of an inch out of line, at work for over two years, and that it continues to work perfectly satisfactory.

We have also since Christmas had a flexible crank-shaft 10 in. in diameter working in a steamer that had previously given great trouble with her crank-shafting, and the same is giving every satisfaction.

Fig. 1 shows transverse section, Fig. 2 section, Fig. 3 end elevation, and Fig. 4 plan of the flexible ball coupling, which may be either a part of each shaft to be coupled, or shrunk or keyed on to plain shafts. The end center of each half coupling is cupped out to receive a ball which is inserted between them. On this ball, which retains the axis of each shaft end, oscillate the two shaft ends when they are revolving with any angular movement. For the purpose of transmitting the rotary motion of one shaft to the other, a disk is formed on each shaft end. Upon the face of each disk are three projecting jaws, A and B, corresponding and engaging with each other. In order to keep the shaft ends in contact with the ball, suitable bolts are passed through both disks, fitting loosely in their bolt holes, and under each nut or bolt head is placed a spring washer. Not only by this arrangement are the parts kept in close contact, but the spring washers admit of the disks simultaneously opening and closing upon each other, and necessarily of the jaws moving deeper into and out of gear with each other alternately at every revolution, when the shafts are rotating with any angular movement. In order to reduce friction to a minimum, a parallel piece made of suitable material is placed between the driving ahead faces of the jaws, A, on the driving shaft and the driven ahead faces of the jaws, B, on the driven shaft. These pieces are lipped under the jaws at the bottom or inner end, to prevent them flying out while in motion. For the purpose of taking up the blacklash and compensating for any wear that might occur on the driving ahead faces of the jaws, adjustable pieces made in wedge form are fitted between the driving astern faces of the jaws, A, on the driving shaft and the driven astern faces of the jaws, B, on the driven shaft, or between the other faces

of the respective jaws if preferred, when parallel face pieces are not used between them.

Each of the adjustable and also the parallel pieces are slightly rounded on both sides, so that they may roll between the jaws in place of sliding when the jaws are accommodating themselves to any angular movement of the shafts.

Each of the wedge pieces is secured and may be adjusted by means of an adjustable ring.

On the inner surface or circumference of this adjustable ring are formed internal cams corresponding with the number of wedge-shaped pieces. These internal cams are in close contact with the outer ends thereof, and by turning the ring around, the cams act upon such outer ends of the wedges, and adjust them between the jaws. After the adjustment has been made, the adjustable ring is retained in its position by inserting blocks of wood or other suitable material between the before mentioned wedge-shaped pieces and heels or ends of the internal cams. Then, after the blocks or packing have been inserted, they are covered by a metal plate, whereby they are held in position; and the whole presents a neat and compact flexible coupling, comparatively inexpensive, but certain in its action.

With this description of the flexible ball coupling, I will now proceed to that of the flexible crank-shaft, or more properly speaking the accommodating web at the end of the crank-pin.

Fig. 5 shows sectional plan, Fig. 6 end elevation, and Figs. 7, 8, 9, and 10 details. In this crank the pin is fitted or carried rigidly with its forward web. The pin-eye of the aftward web is bored out to receive a circular bush, such bush being made convex on its periphery, and through it the outer end part of the crank-pin is passed. The eye into which the bush is received is bored out to a suitable depth and of sufficient diameter to admit of an adjustable ring plate, which is made concave on its inner face to fit upon the outer side of the periphery of the convex bush. A solid web, to permanently fit in the eye of the web a concave ring-plate, which may be secured by the same key that holds the adjustable ring-plate.

The after-crank in a two or three throw shaft constructed on this principle, by any one of the above methods, is flexible, inasmuch as it will permit of the propeller shaft in rigid continuity with the after journal length of the crank-shaft revolving at an angle to the crank section itself.

This flexibility, it will be easily understood from the foregoing description, is attained by allowing the after crank-pin with the convex bush freedom to oscillate in the after accommodating web, as well as being capable of a to and fro movement in the bush, so as to adapt itself to any bending and unbending or opening and closing action of the crank, which takes place alternately in every revolution, if the respective journal lengths are revolving at an angle to each other. This would be the case when the propeller shaft was thrown out of line with the crank section through the straining of the hull of the vessel, or again when the forward or after end of the crank-shaft fell out of line, or when it fell bodily out of line through unequal wear having taken place in the line of bearings.

This crank will also admit of any lateral movement of the propeller shaft when wear has occurred in the thrust block, or when it has not been properly adjusted, as the crank-pin is capable of moving to and fro in the convex bush.

In a double or triple throw crank-shaft a flexible after crank would freely allow of the crank and propeller shaft revolving at an angle to each other, when either the forward end of the former shaft had fallen out of line through unequal wear in its bearings, or when the latter shaft had been carried out of line aftward by the straining of the hull of the vessel. When, however, the after end of the crank-shaft or the shaft bodily falls out of line, circumstances arise which this flexible crank by itself cannot entirely obviate.

For in bending down the end of the propeller shaft, lengths of the propeller shaft, would give all the necessary flexibility. See L and M, Fig. 16, and S and T, Fig. 20.

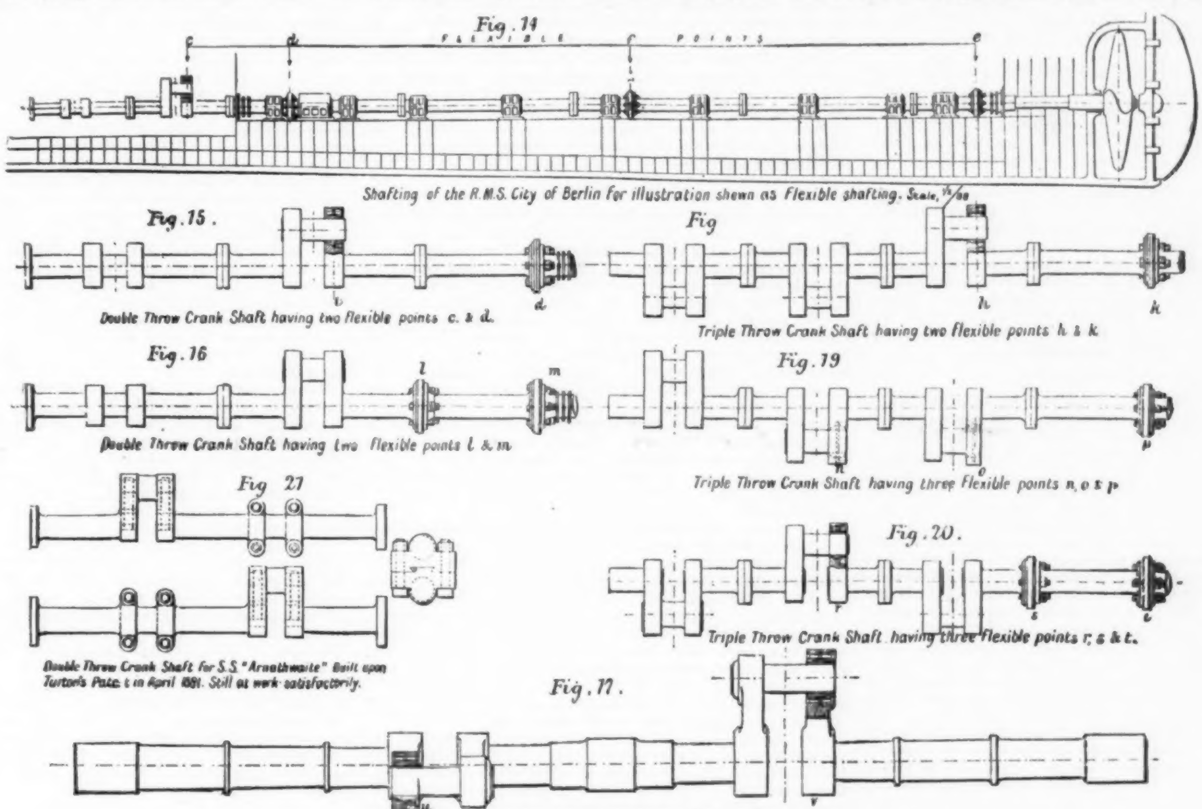
No doubt it would, but the fact that this arrangement would not allow of lateral movement (to the same extent) of the propeller shaft through wear in the thrust block, etc., places it at a disadvantage with the former arrangement, which admits of such movement in the flexible after-crank.

With regard to triple-throw crank-shafts, they may be rendered flexible, not only in their relation with the propeller shaft, but in their own length, by the use of two flexible after-cranks and a flexible coupling between the first and second lengths of the propeller shaft, as shown at NO and P, Fig. 19; or another arrangement would accomplish the same end, though with not the same efficiency, viz., by the use of a flexible middle crank and two couplings, R S and T, Fig. 20.

It need hardly be said that flexible cranks can be used with advantage in a paddle shaft as shown at U and V, Fig. 17, which is an adaptation of the paddle shafting of the royal mail steamer Ireland.

Fig. 14 shows, for the sake of illustration, the crank and propeller shafting of the royal mail steamer City of Berlin, made completely flexible by the aid of an accommodating after-web, C, and three flexible couplings. One, D, between the first and second lengths of the propeller shaft; another, E, between the latter and the tail-end shaft; and the third, F, half way between the two, to save the propeller shaft from bending by its own weight, if one or more of its bearings failed to thoroughly support it. The coupling, E, would permit of the outer end of the tail shaft falling freely when excessive wear had taken place in the stern bush.

Such an arrangement of these couplings, D, E, and F, in combination with the after flexible crank, C, would give complete and perfect flexibility to the whole of the shafting in such a manner that it could adapt itself freely and mechanically to any irregularities that might occur in its line of bearings.



FLEXIBLE CRANKS AND PROPELLER SHAFTING.

corresponding concave part is formed in the other portion of the eye, which in conjunction with the before mentioned ring-plate forms a seating to receive the convex bush, and allows it to adjust itself as required. This bush is split to allow of its being compressed upon the crank-pin by the adjustment of the movable ring-plate, should the parts become worn or slack. The adjustment is accomplished by suitable bolts, the screw-nuts of which bolts are subsequently secured by a lock-plate.

If preferable, the adjustable ring-plate may be screwed into the eye of the web, as shown in Fig. 11.

A square or round headed key placed through the web and secured by a split pin, fitting partly in a groove cut across the screw thread on the periphery of the adjustable and partly in the threaded portion of the eye of the web, prevents the ring-plate from unscrewing.

To readjust the ring-plate, should any wear take place, the key is withdrawn and the ring-plate screwed further in as required, and round to a point where one of the grooves on the ring-plate (there being several cut across its periphery) comes opposite the keyway in the eye of the web, when the key may be replaced and subsequently secured by the split pin.

This arrangement would not only dispense with the retaining bolts, but would encroach less upon the metal between the two eyes of the web, as the ring-plate could then be made less in diameter.

It need hardly be stated that in cases where the sufficiency of metal between the eyes of the web is a consideration, this latter arrangement would have the preference, inasmuch as it leaves the web stronger, and if shortness of stroke is an object, this may be further done by making the web solid with the shaft (Figs. 12 and 13). In this latter case, it might be advisable, on the score of economy of workmanship, instead of forming part of the spherical seating of the bush in the to bring its axis in continuity with the axis of the crank-shaft, one of two evils will be experienced:

Either the crank-pin will be submitted to a bending strain in having to bend down the end of the propeller shaft, or the end of the propeller shaft will have to be held down by the after-bearing cap of the crank-shaft. This bending strain, if taken wholly on the crank-pin, would not, of course, be anything like as distressing as it would in an ordinary built-up or solid crank, but would still exist in a degree greater than is desirable, and the intensity of it would depend on what resistance the propeller shaft offered against being bent. This resistance of the propeller shaft would be the less, the further aft was the first point where the shaft was supported in line, and where the shaft would be bent from. As such shaft would not only be bent through a smaller angle, but would be more easily bent, as the forces tending to bend it would have a greater leverage, consequently a less bending strain would be put on the crank-pin, and the propeller shaft itself would suffer less, inasmuch as it would not be bent so severely. (It may here be remarked that when speaking of a shaft being bent, I do not always mean that it literally is bent, but that it has a tendency to bend.)

From the foregoing remarks, it is obvious that to save the propeller shaft from all undue strains, when the crank-shaft falls in its bearings below the propeller shaft, and to obtain in all other respects, save torsionally, perfect independence and freedom of the crank-shaft in its relation with the propeller shaft, it would be necessary to use a flexible ball coupling between the first and second lengths of the propeller shaft, as shown at C and D, Figs. 14 and 15, and at H and K, Fig. 18.

It has been suggested that two flexible ball couplings, one replacing the flexible after-crank, and used between the crank and propeller shaft, while the other, as before proposed, between the first and second The fact that such has the ability to revolve freely in its bearings under any circumstances should, in itself, be a recommendation for its general adoption. For not only is a minimum of power required to rotate the shafting in its bearings, but vibration, friction, deterioration in the brasses, and above all the danger of a shaft breaking, are reduced to a minimum.

In conclusion, it goes without saying that a crank and propeller shaft must be one of two things—either completely rigid or completely flexible.

So long as half-hearted shafts are used, which are neither one thing nor the other, so long will they continue to wriggle against the inevitable in the vain attempt to retain their true form at the expense of their vitality, decay, and final collapse. All that was feasible and practicable without regard to cost has been done to make the rigid shaft a success in some of the finest vessels recently floated.

But the fact that they have constantly to be lined up in their bearings is evidence that the shafts run the risk of giving way, or have actually been bent at some point or other. Hence it is certain that rigid shafts will still continue to fail, so long as bearings wear unequally and hulls strain. Also, as bearings that will not wear and hulls that will not strain are unobtainable, the only way of consigning broken shafts to things of the past is to elude the evils by using flexible shafting.

THE deepest boring yet made is said to be at Schladebach, near the line between Leipsic and Corbetha. It has been made by the Prussian Government for the purpose of ascertaining the presence of coal, and was bored with diamond drills. Its depth is 1,390 meters, or 4,560 feet, its breadth at the bottom two inches, and at the top eleven inches. The temperature at the bottom indicates 118° Fahr.

RECENT PROGRESS IN CHEMISTRY.*

By Prof. H. CARRINGTON BOLTON.

INTRODUCTORY.

1. To many intelligent and cultivated persons not specifically instructed in chemistry, this word recalls confused memories of colored liquids, glistening crystals, dazzling flames, suffocating fumes, intolerable odors, startling explosions, and a chaos of mystifying experiments, the interest in which is proportional to the danger supposed to attend their exhibition. Further reminiscences are of many singular objects in wood, metal, glass, and earthenware, of flasks and funnels, of retorts and condensers, furnaces and crucibles, together with bottles innumerable filled with solids, liquids, and gases, the whole paraphernalia connected by glass tubes of eccentric curves, and displayed in inextricable confusion and meaningless array. Behind this chaos arise vague memories of one discoursing learnedly in a polysyllabic jargon, and attempting to explain the unusual phenomena by the aid of abstruse hypotheses, but utterly failing to remove the sensations of awe and of mystery bordering on the supernatural which overwhelm the hearer—impressions that have clung to chemistry ever since its entanglement with the superstitions of alchemy, astrology, and the "black art."

Persons who undertake to gain through chemical literature a knowledge of what chemists are doing in and for the world encounter a discouraging nomenclature which repels them by its apparent intricacy and its polysyllabic character. Their opinion of the terminology of an exact science is not enhanced when they learn that "black lead" contains no lead, "copperas" contains no copper, "mosaic gold" no gold, and "German silver" no silver; that "carbolic acid" is not an acid, "oil of vitriol" is not an oil, that olive oil is a "salt," but "rock oil" is neither an oil nor a salt; that some sugars and some kinds of wax are alcohols; that "cream of tartar" has nothing in common with cream, "milk of lime" with milk, "butter of antimony" with butter, "sugar of lead" with sugar, nor "liver of sulphur" with the animal organ from which it was named.

Readers of chemical writings sometimes fail to appreciate the advantages of styling borax, "di-meta-borate of sodium," or of calling common alcohol "methyl-carbinol," and they ignore the euphony in such words as pentamethyldiamidothiodiphenylamindiiodomethylate (a substance begotten and baptized by Dr. Albert Maasen).

Those whose chemical education consisted in attendance on a course of lectures illustrated by experiments performed in their presence, interspersed with occasional recitations from a prosaic text-book which taxed the memory in true Chinese fashion, may be pardoned for retaining very hazy impressions of the true character of the science. On the other hand, many thinking and reading persons recognize the magnitude of the scope and operations of chemistry, and have some appreciation of its benefits to mankind.

CHEMICAL SOCIETIES.

2. The fields of chemistry explored by zealous investigators are prodigious in extent and diversity; in its various sections, analytical, agricultural, pharmaceutical, physiological, and technological, it yields fruit of infinite value to the human race, and, co-operating with other sciences, produces results which promote civilization in the highest degree. So rapidly are new methods of cultivation applied to these fields, so numerous and active are the workmen engaged in tilling them, that the harvest is too abundant for mental storage, and those who survey the operations at a distance are quite unable to apprehend the products. This inability to follow the advances made by chemical science is felt not alone by those whose imperfect and non-technical training has ill fitted them for the task; even the specialist stands aghast at the prospect, and abandoning attempts to apprehend the progress made in all departments, confines his reading and research to a limited number.

The twelve principal chemical societies of the world have an aggregate membership of over eight thousand; nearly all of these members are actively contributing to the advancement of chemical science, publishing their results for the most part in periodicals especially devoted to the subject. Excludin transactions of societies and journals of physics and pharmacy, these chemical periodicals issue annually about twenty thousand pages. Bearing these statistics in mind, are we not justified in feeling appalled at the idea of presenting within the compass of an evening's address a review of recent progress in chemistry? Any attempt to do more than glance at a few salient points is obviously out of the question. "Recent" time will of necessity be a somewhat variable quantity, its limits being determined by expediency. We shall also endeavor to bear in mind the fact that we address an audience not exclusively composed of professional chemists.

NEW ELEMENTS.

3. Much interest is commonly attached to announcements of new forms of matter; an interest out of proportion, perhaps, to the real value of the discoveries. During the last nine years chemists have not failed to sustain this interest, for they have proclaimed no less than thirty-one new elementary bodies. The ambition of these chemists, however, has been greater than their accuracy, for of these thirty-one bantlings but five or six have survived the scrutiny of the doctors, two or three are now in precarious health, and the remainder have been buried or cremated without ceremonies. Of the youthful survivors comparatively little is known; their character is being severely tested, and their future destiny and utility is yet uncertain.

The extreme rarity of the minerals in which the new elements have been detected, the excessivaly small percentages of the new ingredients, the extraordinary difficulties attending their separation from known substances, combine to render the investigations laborious, protracted, and costly. From twenty-four hundred kilogrammes of zinc blende, Lecoq de Boisbaudran, the discoverer of gallium, extracted sixty-two grammes of the precious metal; compared with this element, therefore, gold is both abundant and cheap. Ytterbium, scandium, samarium, thulium, and the rest will long remain mere chemical curiosities known to but few; probably the most sanguine will not claim for them a future place among substances of economic value.

IMPROVED METHODS IN SPECTRUM ANALYSIS.

4. But of far greater importance than the elements themselves is the marvelous delicacy of the means used in detecting and isolating them. When Bunsen and Kirchhof presented to scientists the instrument which combines the penetration of a telescope with the power of a microscope magnified a hundredfold, they were enabled to disclose nature's most hidden secrets. The new elements have been traced to their hiding places, their differences established, and their subsequent purity demonstrated, chiefly by their emission and absorption spectra. Three years ago William Crookes, who had already discovered thallium by the aid of the spectroscope, announced a novel and remarkable extension of the power of this instrument. Crookes found that many substances, when struck by the molecular discharge from the negative pole in a highly rarefied atmosphere, emit phosphorescent light of varied intensity. Having observed under these conditions a bright citron colored band or line, he pursued the substance producing it, and, after a laborious search, found that it belonged to yttrium.

Subsequent studies showed this modification of spectrum analysis to exceed in delicacy all known tests for the rarer earths; yttrium can be detected when present in one millionth part. Within a twelvemonth, Crookes has made known the application of radiant matter spectroscopy to samarium; the delicacy of this test surpasses that for yttrium, and the anomalous behavior of the mixed earths yields phenomena "without precedent."

About the same date as the later communication by Crookes, Lecoq de Boisbaudran published a method of obtaining what he terms "reversion spectra," which is practically the same in effect as that of Crookes. The French savant finds indications of two new elements in certain brilliant lines, but Crookes distinctly warns us that "inferences drawn from spectrum analysis *per se* are liable to grave doubt," and "chemistry after all must be the court of final appeal." Crookes' reflections on the sufficiency of spectrum observations as criteria of the elementary character of bodies are justified by the experience of many, notably of Sorby, whose pseudo jargonium is well remembered. This difficulty arises especially with absorption spectra, and neglect of the warning given by Sorby has led several chemists into fruitless researches.

ATOMIC WEIGHTS.

5. When Dalton, the Manchester schoolmaster, added to the atomic theory of the Greeks the laws of definite and of multiple proportions, he transformed an "interesting intellectual plaything" into an exact scientific theory capable of experimental demonstration. The importance of ascertaining the atomic weights of the elements with the utmost accuracy has stimulated chemists to apply to the problem their best endeavors; and as the methods of analysis become more refined the determinations are again and again repeated, every ascertainable and imaginable source of error being carefully eliminated.

Besides the experimental repetitions, the figures obtained by various observers have recently been submitted to careful recalculations by Clarke, in this country, and soon after by Lothar Meyer and Seubert, in Germany. Their labors give chemists the latest and most reliable constants.

The prevailing, though partly unacknowledged, adherence to Prout's hypothesis, leading chemists to prefer whole numbers (or at least even fractions) for the atomic weights, is liable to result in confusion and perplexity. Stas demonstrated that the atomic weight of oxygen is not quite sixteen times as great as that of hydrogen, but that when $H=1$, $O=15{\cdot}96$. The tendency to disregard this difference of $\frac{1}{400}$ is unfortunate, since important errors in calculations based on organic analyses might result therefrom. Lothar Meyer and Seubert show that in the analysis of compounds of carbon and hydrogen, the error introduced by making $O=16$ is greater than the errors of observation; and in the analysis of a body belonging to a homologous series, doubts might arise as to the identity of the body under examination. Of course, the formula of a body is not determined by analytical data alone; still, this liability to errors marks forcibly the desirability of greater uniformity in the standard of values for the atomic weights.

Contrasting strongly with belief in the absolue character of the weights of atoms is the suggestion of Boutlerow and others that the law of definite proportions is subject to variations. In 1880, Schutzenberger observed a curious anomaly in analyzing some hydrocarbons. He found that the sum of the carbon and hydrogen was 101 for 100 parts of material, the result under other conditions being normal. Boutlerow called attention to this, and expressed the opinion that the chemical value of a constant weight (or rather mass) of an element may vary, and that the so-called atomic weight of an element may be simply the carrier of a certain amount of chemical energy which is variable within narrow limits. At a meeting of the Chemical Society of Paris, where Professor Wurtz presented a summary of the views of Boutlerow, an interesting discussion followed; this subsequently drew from Prof. Josiah P. Cooke, of Harvard, a communication in which he shows that he had expressed similar views more than twenty-five years before. As early as 1855, he had questioned the absolute character of the law of definite proportions, and had suggested that the variability was occasioned by the very weak affinity between elements manifesting a fluctuating composition. These speculations are interesting to theorists, but do not seriously impugn the status of chemical philosophy.

CORRELATION OF ATOMIC WEIGHTS AND PROPERTIES OF BODIES.

6. For many years, chemists have dimly perceived the probable correlation of the properties of the elementary bodies and their atomic weights. Dumas pointed this out for certain marked groups, Newlands emphasized it; but it remained for a Russian chemist, Mendelejeff, to establish, in 1869, a law of great importance. Mendelejeff showed that if the elements are grouped in the order of their atomic weights, it will be found that nearly the same properties recur periodically throughout the entire series. This so-called Periodic Law is more concisely stated thus: The properties of the elements are periodic functions of their atomic weights. The accuracy of the deductions based on this law is strikingly shown by the fact that Mendelejeff, finding an unfilled blank in the periodic system, boldly announced the general and special properties of the element awaiting discovery; six years later, Lecoq de Boisbaudran discovered gallium, an element which proved to have properties almost identical with those of the hypothetical *eka-aluminum* described by Mendelejeff. And in 1879, the accuracy of Mendelejeff's prophecy was further confirmed by Nilson's discovery of scandium, the counterpart of the hypothetical *ekabor*. *Eka-silicon*, though yet to be discovered, may almost be regarded as a known element, so fully have its properties been predicted.

The correlation between atomic weights and physical properties is being extended, and now embraces the fusibility, boiling points, general affinities, color, occurrence in nature, physiological functions, and many other factors. Dr. Carnelley, who has been active in developing this subject, at the Aberdeen meeting of the British Association proposed a "reasonable explanation" of the periodic law; he regards the elements as compounds of carbon and æther, analogous to the hydrocarbon radicals, and suggests that all known bodies are made up of three primary elements, carbon, hydrogen, and æther—an assumption which cannot be disproved.

In recent years the periodic system has exerted noteworthy influence on the classification of the elements and their compounds. It is of positive utility in determining unsettled questions concerning new and rare elements, and is destined to maintain a lasting hold on chemical philosophy.

ORIGINAL FORM OF MATTER.

7. The question whether the known elements are truly primary forms of matter has long occupied the thoughts of chemists, and the problem constantly acquires new features. The influence of high temperatures on the spectra of the metals has been a fruitful source of speculations. In 1878, the English astronomer and physicist Lockyer announced the discovery of the resolution of the elements into one primary matter; but when Lockyer's paper was read before the Royal Society, his discovery proved to be little more than a hypothesis, and that not a new one, he having been virtually anticipated by Professor F. W. Clarke, of Washington. However, Lockyer's hypothesis was based in part upon experimental evidence. After eliminating coincidences in the lines of the spectra of various metals, due to impurities, so large a number of identical lines remained that he advocated the assumption that these are produced by a primary matter common to the so-called elements. He pointed out that in the hottest stars, Sirius for example, hydrogen only is present, and argued that at extremely high temperatures the so-called elements are broken up into hydrogen, the ultimate matter of the universe. Lockyer's announcement excited, temporarily, a lively interest, but his views are not regarded as supported by sufficient evidence.

More recently, the doctrine of "structure" has been borrowed from organic chemistry, and applied to the elementary bodies; the relations existing between the elements is so similar in many respects to the relations between the hydrocarbons in a homologous series, that the element have been regarded as compounds of carbon with an unknown primary form of matter. Experimental evidence is lacking, but the hypothesis takes a plausible form.

Dr. Carnelley, as elsewhere stated, suggests that elements are compounds of hydrogen, with the all-pervading æther of the physicist; but we venture to remark that attempts to explain the nature of elements by assuming them to be compounds of hydrogen with a substance whose very existence is itself assumed is, perhaps, an intellectual amusement, but not likely to advance the exact sciences.

During the past year, an Austrian chemist has announced the decomposition of didymium by purely chemical means, and the discovery of praseodymium and neodymium as its constituent elements. An English chemist claims to have evidence of the existence of an allotropic form of nitrogen. Both these statements await confirmation.

AFFINITY AND CHEMICAL ACTION.

8. The views of chemists concerning the nature of affinity and chemical action are undergoing modifications destined to wield an important influence on the science in the near future. The notion has prevailed, though not distinctly formulated, that the chemical attraction exerted between unlike atoms is a superior sort of cohesion, powerful and absolute; and this force was thought to operate between two elementary bodies directly, without the intervention of a third kind of matter. That this so-called affinity is radically affected by physical state, by heat, and by electricity has been admitted, but the conviction is growing in the minds of chemists that many circumstances influencing the union and separation of elements have been overlooked; they are beginning to believe that chemical action does not take place between *two* substances, and that the presence of a third body is important, if not, indeed, indispensable. Many years ago the word catalytic was coined to describe certain isolated phenomena little understood. These phenomena are familiar to chemists, and the number is increasing; the word catalytic is, however, in disfavor, and the term contact-actions is now current. The well-known influence of finely divided and heated platinum in effecting the union of sulphur dioxide and oxygen, and the action of metallic silver in decomposing ozone without itself undergoing any change, are examples. In these and similar changes, one of the substances indispensable to the reaction remains unchanged, and its role cannot be expressed in equations.

Dulong and Thenard, more than sixty years ago, showed that the temperature of ignition of a mixture of hydrogen and oxygen is lowered to a remarkable degree by the presence of solid bodies of varied nature. Within a few months, Menschutkin and Konowalow have made a study of the influence of asbestos, glass, and other bodies on the decomposition temperature of many organic compounds.

There is another class of reactions in which one body acts upon another only through the aid of a third, which maintains its identity at the close of the reaction, yet is known to be decomposed and recomposed suc-

* A paper recently read before the New York Academy of Sciences.

cessively throughout the operation. By heating a relatively small quantity of cobaltous chloride with bleaching powder, the latter is wholly decomposed, yielding calcium chloride, water, and oxygen, yet at the close of the reaction the cobaltous oxide is found unaltered. It has been shown that it is successively decomposed and recomposed during the operation. In their investigation on "Simultaneous Oxidation and Reduction by Means of Hydrocyanic Acid," Profs. Michael and Palmer consider it probable that many of the most important reactions of animal and vegetable life are due to the intercession of substances which undergo change during the reactions, and in the end return to their original form. They suggest also that some of these reactions seem to be dependent on substances capable of decomposing water into its elements, or into hydrogen and hydroxyl; and when the chemist can command a reagent possessing that property at a low temperature, their imitation in the laboratory may follow its discovery.

ELECTROLYTIC THERMAL CHEMISTRY.

9. That chemically pure zinc is not soluble in dilute sulphuric acid has been known since Faraday's day; that sodium does not combine with perfectly dry chlorine, even if the metal be heated to its fusing point, was shown by Wanklyn in 1869; more recently, Mr. Cowper has found that dry chlorine does not attack Dutch metal; six years ago, Mr. H. B. Dixon demonstrated before the British Association that a well dried mixture of carbon monoxide and oxygen can be subjected to the electric spark without exploding. In March, 1885, Mr. H. B. Baker communicated to the London Chemical Society results of his experiments on the influence of moisture in the combustion of carbon and of phosphorus in oxygen, his conclusions being that the combustion of dry charcoal in dry oxygen is complete and slower than in ordinary moist oxygen. In the discussion which followed Mr. Baker's paper, Dr. Armstrong pointed out the importance of these new facts in defining more accurately conceptions of chemical action, and suggested that chemical action is "reversed electrolysis." In his address as president of the chemical section of the British Association for the Advancement of Science (Sept. 10, 1885), Dr. Armstrong further discussed this subject, and stated that the idea conveyed by the expression "reversed electrolysis" is found in the writings of Faraday, neglect of whose teachings retards the progress of chemistry.

The influence of low and of high temperatures in retarding and facilitating chemical changes is fundamental, but some phenomena not generally known may be appropriately mentioned. Victor Meyer and Langer have shown that whereas chlorine violently attacks platinum at low temperatures, it is without action upon the metal between 300° and 1,300°, and begins to act upon the platinum above the latter temperature, the action becoming violent at 1,600° to 1,700° C.

Liquefied ammonia at —65° does not combine with sulphuric acid, but swims on its surface without mixing with it. Donny and Mareska long ago showed that sodium retains its luster in liquid chlorine at —80°, and quite recently Prof. Dewar demonstrated that liquid oxygen is without action on sodium, potassium, phosphorus, solid sulphureted hydrogen, and solid hydriodic acid. He further experimented with other substances normally active, and found their affinity at very low temperatures destroyed.

NEW VIEWS OF CHEMICAL REACTION.

10. Attempts have been made to solve the problem of a general theory of chemical action by means of the data of electrolysis and of thermo-chemistry. The subject is further complicated by the phenomena of induction, of predisposing affinity, and of influence of mass. Lastly, but not least, the term affinity is itself used in a vague way, expressing different ideas at different times and by different authors, some writers doubting the expediency of employing the word at all, and favoring the more general expression chemical action. The true nature of chemical action has yet to be satisfactorily explained; only the most general conclusions are fairly deducible from the data in hand, namely, that "each chemical substance which forms a member of any changing system exerts a specific action on the course of the changes which that system undergoes."

Chemists are beginning to realize that many phenomena regarded as simple in character are in reality quite complex. A single example must suffice. From Lavoisier's day until a few years ago, the combustion of carbon monoxide in the air or in oxygen was regarded as a very simple phenomenon, satisfactorily explained by the equation:

$$2CO + O_2 = 2CO_2$$

in which two molecules of the gas unite directly with one of oxygen, producing two molecules of carbon dioxide. In 1880, however, Mr. H. B. Dixon demonstrated that this reaction takes place only in the presence of aqueous vapor; this necessitates an entirely different explanation, as indicated in the following equations:

1. $CO + H_2O = CO_2 + H_2$
2. $2H_2 + O_2 = 2H_2O$

that is to say, the carbon monoxide decomposes the water, forming carbon dioxide and setting hydrogen free, which latter gas unites with the free oxygen and thus reconstructs the water.

Within a twelvemonth, however, Traube has shown that carbon monoxide does not decompose water in complete absence of air or oxygen, and hence Dixon's first equation does not represent a fact. Traube also finds that when moist carbon monoxide and oxygen are united by the electric spark, hydrogen peroxide is an invariable product, and he suggests the following explanation of the reaction:

1. $CO + 2H_2O + O_2 = CO(OH)_2 + H_2O_2$
2. $CO + H_2O_2 = CO(OH)_2$
3. $2CO(OH)_2 = 2CO_2 + 2H_2O$

These equations may be interpreted as follows: When the electric spark is passed through a mixture of carbon monoxide and oxygen in the presence of aqueous vapor, the first products are true carbonic acid and hydrogen peroxide; the latter at once oxidizes the carbon monoxide, forming a second molecule of carbonic acid; and, finally, the two molecules of carbonic acid are decomposed, with the formation of carbon dioxide and water.

If Traube's views be sustained, it is evident that so simple a matter as the combustion of carbon monoxide has long been misunderstood, and disregard of the presence of moisture has led to erroneous conclusions.

Chemists sometimes marvel at the blindness of the alchemists, who, though familiar with many chemical processes in which gaseous bodies were evolved, yet disregarded these important factors, and left them for later generations to discover. What will future generations think of us, who fail to take into account accessory bodies indispensable to chemical reactions of the most familiar kind?

CHEMICAL DYNAMICS.

11. The speed of chemical reactions is an important factor in chemical theory, the study of which has but recently begun. Wenzel long ago held that the affinity of metals for a common solvent, such as nitric acid, was inversely as the time necessary to dissolve them, and he experimented with small cylinders, partly protected by wax. Gladstone and Tribe have made attempts to ascertain the rate at which a metallic plate precipitates another metal from a solution, and they announced a definite law. Prof. John W. Langley has since shown that, while their experimental work was correct, their method was faulty, and the results fallacious; he thinks it probable that the true law of chemical action where one metal precipitates another should be thus stated: The time during which one atom replaces another in a compound molecule is constant, and the total rate of chemical action varies directly as the mass of the reacting body in solution.

In his address before the Chemical Section of the American Association for the Advancement of Science, at Philadelphia, Professor Langley discussed the problems of chemical dynamics, and pointed out the rich store of promise in this neglected field. Physics deals with three quantities—space, mass, and time. Chemistry has too long been content with studying the changes of matter in terms of space and mass only, that is to say, in units of atomic weight and atomic volume. The discovery of a time rate for the attractions due to affinity is destined to throw new light on chemical science, and to render it capable of mathematical treatment.

12. A prodigious amount of work has been done in thermo-chemistry, and within a few years the multitude of isolated observations have been collected, classified, and made available. The importance of this undertaking will be more appreciated in the future than it has been in the immediate past.

In all cases of chemical change, energy in the form of heat is either developed or absorbed, and the amount is as definite in a given reaction as are the weights of the substances concerned; hence, measurement of the quantity of heat set free or absorbed in chemical reactions often enables the chemist to determine the true nature of the change. For example, the exact condition of certain bodies in solution can only be conjectured from certain physical characters, few and ill-defined; but by thermic methods of investigation the bodies formed can be accurately ascertained. This is accomplished by reference to the law of maximum work. "In any reaction, those bodies, the formation of which gives rise to the greatest development of heat, are formed in preference to others." Thus the thermometer alone in skillful hands determines the *a priori* necessity or impossibility of a reaction.

Berthelot, in Paris, and Thomsen, in Copenhagen, have pursued the subject of thermo-chemistry with indefatigable zeal, and their published results form monuments of exhaustive research. "By the labors chiefly of these two men, we now know the thermal values corresponding to many thousands of chemical reactions. We have learned that the energies of a reaction which can be brought about in two methods, either in the dry way or by solution, differ in the two cases; that salts in solution are in a partial state of decomposition; that the attraction of a polybasic acid radical is not the same for the successive portions of base added, and that the behavior of a monobasic acid in solution differs essentially from that of a dibasic or tribasic acid. We also know that the total energy involved in any reaction is largely influenced by the surrounding conditions of temperature, pressure, and volume."

CHEMICAL PHYSICS.

13. The interesting border line between chemistry and physics is an increasing subject of research on the part of both the chemist and the physicist. The periodic press chronicles profound studies of the relations between chemical constitution and the phenomena of diffusion, of capillarity, of dialysis, of dissociation, and of the law of isomorphism. We read investigations on the value of the theory of atomicity, and on the nature of nascent action. Researches in the domain of electro-chemistry, especially in connection with the various forms of storage batteries, and in relation to the methods and results of electrolysis, are of such importance as to merit a whole address. The press also records numerous studies in actinometry, of the relations between chemical composition and fluorescence and phosphorescence, as well as of polychroism, and of the results of spectrum observations. Noteworthy are the special applications of optical methods to the determination of molecular structure, viz., the relations between chemical composition and 1, the refractive power; 2, the power of rotating a ray of polarized light; and 3, the absorption spectra of both inorganic and organic bodies.

Bruhl has attempted to show that the relationship between refractive power and molecular structure is dependent on the valencies of atoms and on the distribution of atomic interactions. Van 't Hoff has developed a hypothesis of a crystallographic character that cannot be discussed in the brief space at our command.

LIQUEFACTION OF GASES.

14. The meeting of the French Academy of Sciences, held the day before Christmas, 1877, was rendered memorable by the announcement that oxygen gas had been liquefied by two independent experimenters. Previous to that date, hydrogen, oxygen, nitrogen, nitric oxide, marsh gas, and carbon monoxide had resisted all attempts to liquefy them, whether in the hands of the skillful Faraday, the ingenious Natterer, or the learned Andrews. Physicists and chemists, while admitting the class of so-called permanent gases, had for many years looked forward to their eventual liquefaction, yet the final success came as a surprise. This success was the result of the enterprise and ingenuity of a French ironmaster, M. Cailletet, and of a Genevan manufacturer of ice machines, Raoul Pictet, working independently. In each case, the process consisted in simultaneously exposing the gases to a very high pressure and a very low temperature. Pictet obtained the necessary pressure by generating the oxygen in a wrought iron vessel strong enough to withstand an enormous strain, and the low temperature was secured by the rapid evaporation of liquid carbonic acid; Cailletet, whose apparatus was marked by extreme simplicity, obtained the great pressure by means of a hydraulic press, and the low temperature by suddenly diminishing the pressure upon the compressed gases. Descriptions of apparatus without diagrams are seldom intelligible; in this place they are superfluous, for we deal with results rather than with methods. Being ignorant of the "critical point" for oxygen, both experimenters employed a much greater pressure than necessary.

Since the initial successes, the problem of liquefying the quondam permanent gases has been successfully attacked by several experimenters, especially by Wroblewski and Olzewski, whose names indicate their nationality. By employing liquid ethylene (which boils *in vacuo* as low as —150° C. [—238° F.]) as a means of cooling the gases under pressure, both oxygen and nitrogen, as well as atmospheric air, have been liquefied at very moderate pressures.

Among the interesting results obtained are the following: At —102° C. (—152° F.), chlorine forms orange-colored crystals; at —115° C. (—175° F.), hydrochloric acid is a solid; at —118° C. (—180° F.), arseneted hydrogen forms white crystals; at —129° C. (—200° F.), ether solidifies; at —130° C. (—202° F.), absolute alcohol solidifies; at —184° C. (—299° F.), oxygen boils; at —191·2° C. (—312° F.), air boils; at —205° C. (—337° F.), air boils *in vacuo*. These extraordinary temperatures were measured by means of a hydrogen thermometer and by a thermo-pile. The lowest temperature measured (to date) is —225° C. (—373° F.), which was reached by reducing the pressure of solid nitrogen to 4 mm. mercury (Olzewski). Further noteworthy results are as follows: Nitrogen was obtained in "snow-like crystals of remarkable size;" the liquefaction of air has been so conducted as to obtain two distinct liquids separated by a perfectly visible meniscus (Wroblewski); and finally, when hydrogen was subjected to between 100 and 200 atmospheres pressure in small glass tubes surrounded by oxygen boiling *in vacuo*, it condensed to colorless drops.

These noteworthy results are triumphs of physics rather than of chemistry, but no review of chemical progress can afford to omit them; their bearing on the molecular theory of matter justifies the space given them. It seems probable, moreover, that every known substance on the face of the earth will be eventually obtained in solid form by the mere withdrawal of heat. At these low temperatures, the chemical activity of bodies is greatly lessened or ceases, but additional observations must be made on this point before attempting generalizations.

Experiments of the character described demand great resources and are not devoid of danger; those conducting them will be rewarded by undying fame.

CHEMICAL INDUSTRIES.

15. The progress of chemistry in its more material aspects is characterized by the improved and economic production of known substances, by the discovery and manufacture of entirely new ones, and by novel applications of both these classes as well as of waste materials. The necessity of utmost condensation precludes enumeration of even a centesimal part of the processes and products, nor would the mere catalogue be profitable. Omitting for the present the prolific department of organic chemistry, brief mention may be made of improvements in the metallurgy of nickel (now known to be malleable and ductile), of attempts to cheapen the production of aluminum, of the revival of the barium dioxide process for manufacturing oxygen on a large scale, of novelties in artistic keramics, of the industrial production and application of the rare metal vanadium, of the successful introduction of water gas as an illuminating agent, and of constant activity in the fascinating field of photography.

No chemical manufactures are more important than those grouped under the name "alkali industry," which comprises the production of those adjuncts of civilization, carbonate of soda, caustic soda, bicarbonate of soda, and bleaching powder. Conducted by the methods originated by the ill-fated Nicolas Leblanc, they have, after a century's successful career, begun to give way to a youthful rival. The struggle to maintain the supremacy of Leblanc's process has been severe, the problem being a purely financial one. At first the profits were made exclusively on the soda; then the decreasing profits, as well as the necessity of condensing the torrents of hydrochloric acid, led manufacturers to add to the production of alkali that of bleaching powder, and the latter then yielded the profits, while the soda became a by-product. Sharp competition in England and France pushed prices below profitable production, and capitalists with millions involved found their chemical ingenuity severely taxed. Various economical methods of recovering waste byproducts were adopted, and finally attention was turned to the "burnt ore," or "pyrites cinders," obtained in roasting pyrites for the sulphuric acid; this is now treated for copper, silver, and, to some extent, for gold. A Spanish company owning enormous deposits of pyrites on the Rio Tinto, plan to establish in France alkali works, with the intention of deriving their profits solely from the residual oxide of iron and the copper.

Forty-eight years ago, alkali manufacturers might have seen a cloud arising, no bigger than a man's hand, which gradually grew darker and heavier, and now threatens to overwhelm the Leblanc process. Dyer and Hemming patented the so-called "ammonia process" for manufacturing soda in 1838; Schlösing and Rolland attempted to carry it out practically in 1855, but it was not found profitable. The credit of overcoming the practical difficulties, and placing the process on an economical basis, belongs to Solvay, of Brussels, who began to manufacture so-called "ammonia

soda" in 1866. Commencing with the modest yield of 179 tons in that year, he increased it in ten years to 11,580 tons, and in 1883 about 40 per cent. of all the soda made on the Continent was produced by the ammonia process. The success of the new process has completely killed the Leblanc method in Belgium, and has caused the closing of many works in England. A drawback to the new process is that no hydrochloric acid is produced, yet chloride of lime is always in demand; hence a high authority, Dr. Lunge, thinks that in the future the two processes will, of necessity, exist side by side.

NOMENCLATURE.

16. In modern chemical literature by far the greatest amount of space is occupied with researches and discoveries in organic chemistry. To the non-professional reader the peculiarly technical language, abounding in words of unusual length, is not only incomprehensible, but positively forbidding. A vocabulary which contains such terms as toluyldiphenyltriamidocarbinol acetate and methylorthomonohydroxybenzoate does not encourage the casual reader; and when he learns the first-named body is the dye-stuff commonly called magenta, and that the second is the innocent oil of wintergreen, surprise gives way to feelings of despair. When one is gleefully informed that a distinguished foreigner has discovered that orthobrombenzyl bromide treated with sodium yields anthracene, which heated with nitric acid yields anthraquinone, and that anthraquinonedisulphonic acid fused with potassium hydroxide furnishes dioxyanthraquinone, the lay hearer can hardly be expected to become enthusiastic over the announcement; and yet these operations conducted in the private laboratory of a man of genius have been of direct benefit to mankind, setting free thousands of acres for the production of breadstuffs, and establishing industries employing a multitude of workmen. In a word, these abstruse phrases describe the artificial production of alizarine, the valuable coloring matter of madder.

The polysyllabic nomenclature now prevailing expresses to the chemical mind the innate structural composition of the body named; of late years, the words are formed by joining syllables to an almost indefinite extent, and a distinguished chemist has recently urged the advantages of empiric names in place of the unwieldy system. Whether Dr. Odling's plea will produce a reaction in favor of empiric names remains to be seen.

PROGRESS IN ORGANIC CHEMISTRY.

17. To enter into details concerning the recent progress of organic chemistry, and to make them intelligible to an audience not composed of well-read professional chemists, is an undertaking of doubtful success; we will content ourselves chiefly with generalities.

That remarkable product of nature, petroleum, continues to occupy the studies of chemists at home and abroad. Newly invented methods of fractional distillation have disclosed previously unsuspected constituents and peculiarities. Lachowitz has found in the petroleum of Galicia several members of the aromatic series; Mendelejeff has noticed abnormal relations between the specific gravity and boiling points of successive fractions in distilling American petroleum. The various commercial products from crude petroleum, rhigolene, vaseline, paraffine, etc., continually find new and useful applications, their names being household words.

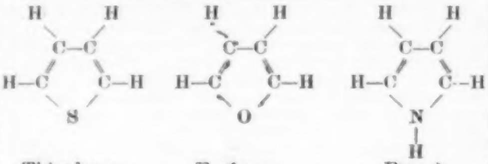
The industrial and scientific novelties in the important groups of oils and fats, alcohols and acids, cannot be specified. After cane sugar, glucose is receiving the most attention; in the U. S. and Germany are sixty manufactories of the various grades of starch sugar, the annual home production alone being valued at $10,000,000. Glucose is extensively used as a substitute for cane sugar in the manufacture of table sirup, in brewing, in confectionery, in making artificial honey, and in adulterating cane sugar, as well as in many minor applications. Recent experiments by Dr. Duggan, of Baltimore, show that glucose is in no way inferior to cane sugar in healthfulness. Much work has been done on sorghum by Dr. Peter Collier, and the first complete examination of maple sugar has lately been made by Prof. Wiley, of the Department of Agriculture. Lovers of the latter sweet will be pleased to learn that it can be made by adding to a mixture of glucose and cane sugar a patented extract of hickory bark which imitates the desired flavor.

The great demand for high explosives as adjuncts to engineering, mining, and military operations occasions constant experimentation; besides the invention of mere empiric mixtures of known substances, chiefly nitro compounds, much work is done of a purely scientific nature, such as investigations on the chemical reactions and products of explosive mixtures, on the heat disengaged by their explosion, on the pressure of the gases produced, and on the duration of the explosive reaction. Thanks to the "Notes" of Prof. C. E. Munroe, of the U. S. Naval Acadmey, chemists are informed of the freshest novelties in this department, rendering further mention superfluous.

RESEARCHES IN THE AROMATIC SERIES OF COMPOUNDS.

18. The researches of chemists in the aromatic series outweigh in both number and importance those in all other sections. The once despised refuse coal-tar has created an entirely new chemistry, and, in its products and derivatives, is by far the most promising field for investigators. The compounds of the aromatic series have afforded some of the most notable successes in synthetical chemistry, as well as some of the most useful substances for dyeing, for hygienic and medicinal purposes. The oil obtained in the dry distillation of bones, a subject of classic investigations by Anderson, of Glasgow, forty years ago, has recently acquired new interest; one of its constituents, pyridine (C_5H_5N), has been obtained in several ways, which show that it bears the same relation to certain acids derived from natural alkaloids, such as quinine, nicotine, etc., that benzene does to benzoic and phthalic acids. These facts point to the possible artificial preparation of quinine at no distant day. This view of the constitution of the alkaloids is confirmed in many ways, notably by Landenburg's discovery that piperidine, a base occurring in pepper, is hexahydrobenzene.

The discovery, by Victor Meyer, of thiophene, a constituent of coal-tar benzene, having sulphur in its composition, is of more than passing interest. Meyer assigns to thiophene a structural formula which shows its analogy to furfuran and to pyrrol. This is indicated in the following graphic formula:

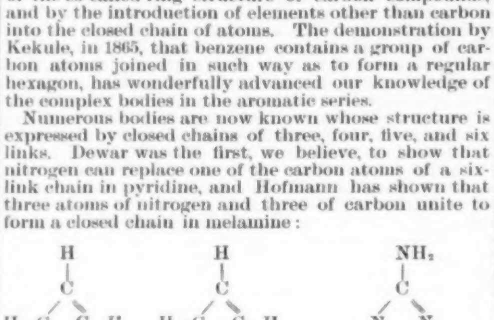


Thiophene. Furfuran. Pyrrol.

SAME SUBJECT CONTINUED.

19. Professional chemists note with interest the important avenues of research opened up by the extension of the so-called ring structure of carbon compounds, and by the introduction of elements other than carbon into the closed chain of atoms. The demonstration by Kekule, in 1865, that benzene contains a group of carbon atoms joined in such way as to form a regular hexagon, has wonderfully advanced our knowledge of the complex bodies in the aromatic series.

Numerous bodies are now known whose structure is expressed by closed chains of three, four, five, and six links. Dewar was the first, we believe, to show that nitrogen can replace one of the carbon atoms of a six-link chain in pyridine, and Hofmann has shown that three atoms of nitrogen and three of carbon unite to form a closed chain in melamine:



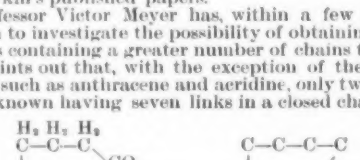
Benzene. Pyridine. Melamine.

It has been a matter of surprise that no series intermediate between the open chains of the paraffine group and the closed ring of the benzene group have been made known. Quite recently, W. H. Perkin, Jr., in a remarkable memoir, has begun to fill up this wide gap, and he describes many bodies containing a three-carbon atom ring, a four and a five carbon atom ring. The series of possible methylene-addition products is shown in the following schedule:

Methylene.	Di-methylene.	Tri-methylene.
$=CH_2$	CH_2 $\Vert$ CH_2	H_2 C $H_2C - CH_2$
Tetra-methylene.	**Penta-methylene.**	**Hexa-methylene.**
H_2C-CH_2 $\vert \quad \vert$ H_2C-CH_2	H_2 C $H_2C \quad CH_2$ $\vert \quad \vert$ $H_2C \quad CH_2$	H_2 C $H_2C \quad CH_2$ $\vert \quad \vert$ $H_2C \quad CH_2$ C H_2

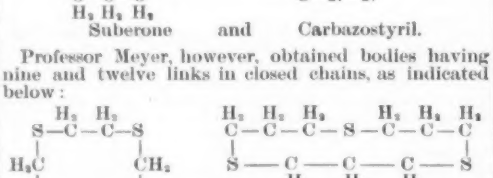
For details concerning derivatives of the above series, and the remarkable properties of some, we must refer to Perkin's published papers.

Professor Victor Meyer has, within a few months, begun to investigate the possibility of obtaining closed chains containing a greater number of chains than six. He points out that, with the exception of the double rings, such as anthracene and acridine, only two bodies were known having seven links in a closed chain, viz.:



Suberone and Carbazostyril.

Professor Meyer, however, obtained bodies having nine and twelve links in closed chains, as indicated below:



These are substances of little stability, as indeed might be expected.

Professional chemists also acknowledge the marvelous success in unraveling the complications of isomerism, and the important aid afforded the study of isomeric bodies of the aromatic group by the doctrine of *orientation*. These rather technical details can receive, however, but brief mention, though a whole series of lectures could be devoted to the fascinating topic. Leopold Gmelin, when writing his "Handbook of Chemistry," in 1827, requested organic chemists to stop making discoveries, or else he could never finish! And during the sixty years which have elapsed, the activity in organic chemistry has been unceasing; yet the extraordinary number of facts now known is not so great as those which the prophetic eye sees disclosed by these recently revealed lines of investigation.

SYNTHESIS OF ORGANIC COMPOUNDS.

20. The crowning glory of chemistry is the power of producing, in the laboratory, from inorganic matter, substances identical with those existing in the vegetable and animal kingdoms. Belief in the mysterious vital force operating in living beings received a rude shock at the hands of Wohler, sixty years ago, and successive triumphs in synthesis have dispelled it entirely, so far as non-organized bodies are concerned: "To-day we know that the same chemical laws rule animate and inanimate nature, and that any definite compound produced in the former can be prepared by synthesis as soon as its chemical constitution has been made out." Within a few years chemists have announced the synthesis of many acids, essential oils, alkaloids, glucosides, dyestuffs, and other bodies naturally occurring in the organic world, and so rapidly do these announcements succeed one another that expectation has displaced surprise. Noteworthy are the following: Alizarine, the valuable coloring matter of madder; vanilline, the aromatic principle of the vanilla bean; cumarine, the aromatic principle of the tonka bean; indigo the well known dyestuff; uric acid, an animal product; tyrosin, likewise a product of the animal organism; salicine, daphnetine, and umbelliferone, natural glucosides and related bodies; piperidine, a constituent of pepper; and cocaine, the new anæsthetic. Besides these, many syntheses have been accomplished of bodies isomeric and not identical with the natural products.

The alchemists labored to transmute base metals into noble ones, and were destined never to realize their ambitious designs; modern organic chemists, operating on substances compared with which even the base metals are precious, produce articles more beneficial to mankind than gold itself, and, at the same time, gain, indirectly, no small store of the coveted metal.

PHYSIOLOGICAL AND SANITARY CHEMISTRY.

21. The application of chemistry to physiology encounters the most complex and difficult problems in the science, and at the same time aims to accomplish the most beneficent results. "The physiologist complains that probably ninety-five per cent. of the solid matters of living structures are pure unknowns, and that the fundamental chemical changes which now occur during life are entirely shrouded in mystery. It is in order that this may no longer be the case that the study of carbon compounds is being so vigorously prosecuted." It may seem strange to the non-professional in this audience that, in spite of persistent and skillful attempts to solve the problem, chemists are obliged to admit ignorance of the exact composition of so common a substance as the white of egg; yet until they acquire an accurate knowledge of the constitution of albuminous substances, the processes of animal economy cannot be explained. While the physiologist, in some degree, waits on the organic chemist for further developments, the latter discovers and prepares novel bodies much faster than the physiologist ascertains their influence on the animal economy. To the joint labors of chemists and physiologists are due the blessings of anæsthetics, hypnotics, and other conquerers of suffering and disease. The anæsthetic properties of cocaine, and the circumstances of their discovery, are matters of popular knowledge. Within a twelvemonth, ethylurethane has been added to the list of hypnotics.

In recent years sanitary chemistry has acquired great importance, and now occupies a distinctly defined field, including all that pertains to the hygienic value of foods and beverages, their adulterations and their fraudulent substitutes; questions of gas and water supply; of the uses and abuses of disinfectants; of household ventilation; and of the diverse matters grouped under the term chemical engineering. Of this very practical branch of chemical science, as well as of the valuable additions to materia medica, of the improved methods introduced into analytical chemistry, and of the ever increasing contributions to the chemistry of agriculture, no mention can be attempted.

CONCLUSION.—GENERAL VIEW OF TENDENCY OF MODERN CHEMISTRY.

22. The tendency of modern researches in chemistry is to magnify the atomic theory; the rapid accumulation of facts, the ever increasing ingenious hypotheses, the most searching examinations of co-ordinate laws, all tend to strengthen the Daltonian adaptation of the philosophic Greeks. Here and there a voice is raised against the slavish worship of picturesque formulæ; but against the molecular theory underlying the symbolic system so depicted, few earnest arguments are advanced. The whole aim of organic chemistry is directed to the discovery of the arrangement of atoms within the molecule, and the success obtained justifies the hypothesis. The edifice erected through these achievements, though young in years, is too substantial to tolerate displacement of its corner-stone. The absolute truth of the atomic theory is beyond man's power to establish; even admitting that it necessitates absurd assumptions, it is, nevertheless, indisputably the "best existing explanation of the facts of chemistry as at present known."

A noteworthy feature of existing chemical research is the recognition of the necessity of a more intimate knowledge of the connection between physical characters and chemical constitution. In the past, chemists increased the number of new compounds so rapidly that they often neglected detailed examination of their physical properties, their relations to known bodies, and to each other, preferring to satisfy their ambition by fresh discoveries. This race after new bodies still continues, but parallel with it are zealous investigators striving after a knowledge of the innate qualities and bearings of these same bodies; and the latter class of students is gaining prizes no less valuable than those secured by the former.

Chemists are also recognizing the necessity of a more minute study of the simpler phenomena of chemistry, and it is in this direction they look for many laurels in the future. Priestley's day of great discoveries by the simplest means has in one sense passed; the opportunities for isolating nine new gases, or of recognizing by chemical tests half a dozen new elementary bodies in the space of a lifetime, are gone; only by the employment of the most delicate appliances, by the closest scrutiny of phenomena and the conditions governing them, by availing themselves of all the resources of physics, by an unshrinking expenditure of time and of money, to say nothing of the necessity of trained mental powers of no low order and of skilled hands, shall chemists in succeeding generations realize their ambitious designs.—*Transactions N. Y. A. S.*

A MISSIONARY reports that the River Euphrates bids fair to disappear altogether in the spreading marshes just below Babylon, which have ruined the steamboat channel and are now obliterating navigation for row-boats.

ON THE USE OF MODELS FOR INSTRUCTION IN THE MAGNETISM OF IRON SHIPS.

THE deviations of the compass produced by the iron used in the construction of wooden ships was a source of considerable perplexity to the navigators of the last and early part of the present century; and no sooner were these difficulties fairly overcome than the building of ships entirely of iron commenced.

With the introduction of iron ships, prolonged investigations into their magnetism and the resulting deviations of the compass on board were undertaken by some of the most eminent philosophers and mathematicians of the day, the subject being still one which occupies the attention of many observers, from the increased use of iron in the equipment, as well as construction of the hulls and decks. These investigations were much facilitated by the increased knowledge of the earth's magnetism, which received such notable additions from the magnetic surveys made by travelers on land and navigators at sea during the years 1819-45.

Moreover, as time rolled on, these observations were embodied in trustworthy graphic representations of the declination or variation, the dip or inclination, and the horizontal force, which have done such good service in the work of obtaining a clear understanding of the cause of the magnetism of iron ships, and the changes to which such magnetism is liable when the vessel's position is altered either geographically or in respect to the magnetic meridian.

It is not here intended to enter into any historical *resume* of the names of the several investigators in this branch of science, nor of the results which each obtained, but to indicate at once where the physicist and mathematician may find the theory and examples of its application; also, how the practical results of this elegant theory may, by the use of models, be made intelligible and available to the seaman and other inquirers who have neither the time nor the opportunity for abstruse studies requiring considerable mathematical knowledge.

The text-book which is now generally accepted in all countries is the "Admiralty Manual for the Deviations of the Compass," in Appendix No. 1 of which will be found the three fundamental equations of Poisson, which form the whole theory of the deviations of the compass, and the expressions of these equations "in terms of the quantities which are usually given and required," written by the late Archibald Smith, M.A., F.R.S.

The whole of the action of the soft iron of a ship is represented in these equations by the parameters *a, b, c, d, e, f, g, h, k*, and in a model by nine soft iron rods fixed in definite positions, distinguished by the same letters.

The effects of the magnetism of the hard iron of the ship are represented in these equations by the parameters P, Q, R, and in the model by two permanent magnets held horizontally in definite positions, and a third permanent magnet held vertically under the compass.

One of the most important contributions to magnetical science as regards iron ships was made by Sir George Airy (late Astronomer Royal) in a paper published in the *Phil. Trans.* Royal Society for 1839. After making a series of experiments in certain iron built ships, he discussed the results mathematically with the purpose of discovering a correction for the deviation of the compass. He concluded his paper with the announcement of his invention of the system of correction by magnets and soft iron, which is universally practiced in the present day, always with advantage, and often as a matter of necessity in ships of certain types, where to find a suitable place even for the standard compass is a matter of no small difficulty. This system of correction, coupled with the analysis described in the "Admiralty Compass Manual," provides the means of correcting a compass even in position on the 'tween decks of our armor-plated ships of war.

With these preliminary remarks, the description of some different forms of models will be given, and their uses for instruction in the magnetism of iron ships considered.

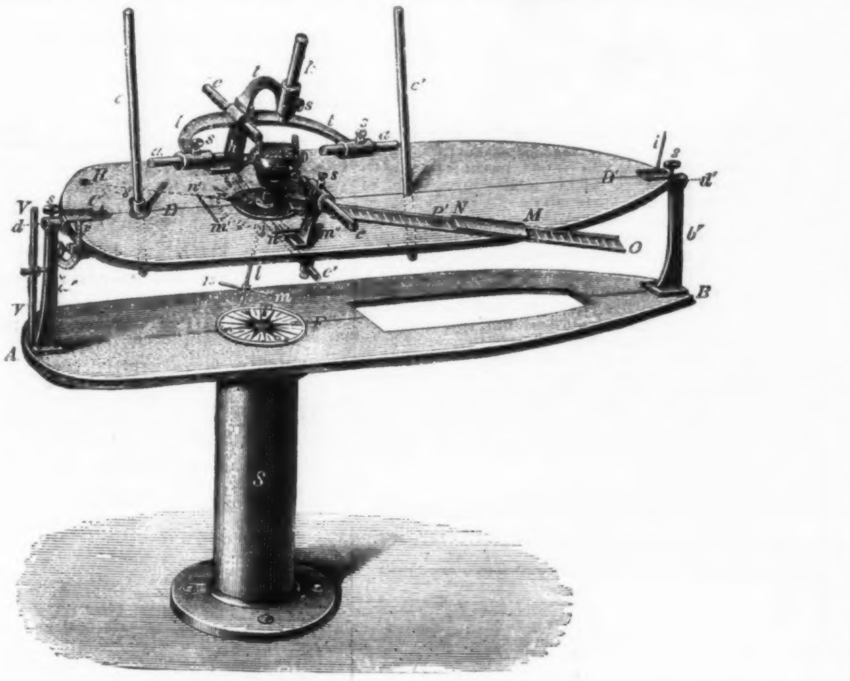
One of the first of these instructive models was that constructed for Sir George Airy, and used during his lectures to illustrate his method of correction of the deviations of the compass. It consisted of a model of the wooden hull of a vessel. In the center of the deck a compass was mounted, disturbing magnets and pieces of soft iron being concealed underneath it, producing semicircular and quadrantal deviations, as in an iron ship. These deviations were then corrected by placing the model ship with its bow alternately on the north and south magnetic points, when the compass was made to indicate the same directions by means of transverse magnets on the deck; and then on the east and west points magnetic, the correction of the semicircular deviation being completed by longitudinal magnets on the deck. Lastly, with the model placed in a northeast and southwest direction magnetic, scrolls of soft iron were placed on either side of the compass—an imaginary line transverse to the model passing horizontally through the center of the scrolls and compass card—until the compass pointed correctly.

Of more recent models there are three which are of an instructive character: one designed by Dr. Neumayer of the German Naval Observatory at Hamburg; the second in England by an official of the Board of Trade; and the third, which is the most complete both for experiments and purposes of instruction, by the United States Navy Department.

The accompanying wood cut on the scale of one-twentieth of the original model is taken from Paper No. 2 of the *Archiv der Deutschen Seewarte*, VI. Jahrgang, 1883, where an account of the experiments to be made with it is given in full detail. The following is a description of the several parts shown:

S is a pillar fixed in the floor of the room, upon which pivots the wooden board, A B, with the line of its central axis marked. At the point, T, a compass card is fixed to S, with its north and south points adjustable in the magnetic meridian.

Supported by the two brass uprights *a' b'*, is the second board in the form of a ship's deck pivoting at *d d'*, so that it can be inclined sideways, as when a ship inclines under pressure of sail or when rolling,



THE MAGNETISM OF IRON SHIPS.

but kept horizontal as required by the screws, *s s*. An arc, *o p*, marked to degrees, shows the angle of inclination. A gimbaled compass, C, with sight vanes, is mounted on the deck, and when the lubber's point and the pin, *i*, are in line, as seen through the vanes, the compass support is secured by the clamping screw. O P' is a graduated arm revolving round the base of the compass stand, grooved to receive a bar magnet, and with a pointer, *r*, showing the number of degrees the arm has been turned in azimuth. *h* and *h'* are brass bearers for carrying the rods of soft iron used in disturbing or correcting the compass, with screws, *s*, for clamping the rods at any required distance.

The model, as described thus far, is entirely free from any magnetic body external to the compass, and may, by means of the latter, be placed with its marked axis in the magnetic meridian, the compass card at T being fixed in that direction for future reference. The means for producing the disturbing forces on the compass similar to those found in iron ships are these. M N is a magnet, which may be so adjusted in the groove that, by moving the arm, O P', in azimuth, semicircular deviation of any desired form may be produced. In the figure, the magnet, M N, is placed to produce the semicircular deviation of a ship built with her head north-northwest, and the resulting south (or blue) pole is found in the point, R. The soft iron rod, V *v*, in its vertical position represents the sternpost of a ship, producing that part of the semicircular deviation in compasses placed near it which changes as the ship moves into fresh magnetic latitudes. *c c'* are soft iron rods, intended to represent iron masts.

Quadrantal deviation of the form generally observed is produced by the soft iron rod, *e'*, extending from side to side under the deck, DD', like a deck beam, the rods, *a a*, also conspiring with *e'* in increasing the quadrantal deviation. That part of the heeling error caused by the magnetism of the hard iron of a ship is produced by a small vertical magnet in the position of the rod, *l*, when removed; that from soft iron by the vertical soft iron rod, *k*, and the horizontal rod, *e'*.

The compass, C, having been disturbed by magnetic forces of the usual type in an iron ship, may now be corrected; *m° n°* is a magnet with its north or marked end, *n°*, toward the stern of the model, and near enough to the compass to correct the deviation on the east and west points; *m' n'* is a second magnet, with its north or marked end, *n*, toward the port side, correcting the deviation on the north and south points. Or the whole semicircular deviation may be corrected by one magnet, *m n*, placed exactly in the direction of R, *n* being the marked or north end. The quadrantal deviation is corrected by the rods, *e e*. The heeling error caused by *e'* is also nearly corrected by *e e*, and that caused by the sum of the effects of *k* and the vertical magnet under the compass by another vertical magnet with the opposite pole uppermost.

Thus it will be seen that any component part of the whole deviation usually found at the standard compass of an iron ship may be produced in the model, and the corresponding corrector provided.

The portable model adopted by the Board of Trade has a compass mounted on a ship's deck, as in the figure; but the deck, which rests on a central metal support, revolves around a pivot in the center of a fixed board, an arrangement for inclining the model being provided.

The disturbing magnets and soft iron are arranged thus: For producing the semicircular deviation due to the hard iron of a ship, thin magnets are placed as required in any of the grooves cut in the deck radiating from the center of the compass, so that deviations due to any direction of the ship's head while building may be produced. For that part of the semicircular deviation due to soft iron, a vertical soft iron bar is fixed in the central longitudinal line of the deck and near the stern. For the quadrantal deviation, hollow cylinders of soft iron are placed under the deck similar to the rod, *e'*, of the figure. For the heeling error due to hard iron, a magnet is placed vertically under the compass.

The correctors are magnets placed on the deck, as *m' n'*, *m° n°*, in the figure, and soft iron spheres—on brass brackets which may be turned in azimuth around the compass—instead of the rods, *e e*; a Flinder's or vertical soft iron bar before the compass; a vertical magnet under the center of the compass, to correct the heeling error.

This model is exceedingly well adapted for instruction and examination in the causes of the deviations generally found at standard compass positions in the mercantile navy, and the method of correction adopted in that service.

There remains now only the model made for the Bureau of Navigation of the United States Navy Department to be noticed. It consists of a miniature vessel of which the stem, keel, and sternpost are of bronze cast in one piece, with three wooden decks supported by bronze screws. This model, called the Scoresby, is pivoted at the stern by a socket in the floor, with a bronze wheel fitted under the bow, so as to be easily turned around in azimuth. The disturbing magnetic forces are produced by magnets and hollow wrought iron tubes of soft iron, while wrought iron plates can be attached to the sides of the vessel.

The Scoresby was designed with the object of proving by experiment the mathematical theory already noticed. Experiments were consequently made as to the effects of hammering the plates of the model with the bow in different directions, a magnetic survey being made after the hammering to determine the polarity in different sections, and its degree of permanency or otherwise. The model was next swung both when upright and inclined, for the deviations of the compass produced by a magnet or soft iron tube representing each parameter singly, combinations being made afterward as desired. These experimental results proved satisfactorily the correctness of the mathematical theory.

This general description of the Scoresby will serve to show that the Americans have taken considerable pains in making valuable experiments in proof of theory, and for instruction to the seaman. Before parting with her, however, a quotation from the American professional paper on the subject of the Scoresby seems worthy of a place, as sounding a fresh warning note to those who ruthlessly distribute iron *ad libitum* and in any form around the position of a ship's standard or guiding compass:

"Compensation of large deviations by means of magnets is at the best but a remedy for an ailment; better not sow the seeds of the disease."

The three models just described have been selected as being the most modern specimens of these useful aids to knowledge, but there are others for the instruction of officers in the Royal Navy which have been in use for some years past. It will be gratifying to the many who take interest in maritime affairs to note the increasing anxiety for the spread of a sound knowledge of the principles of the magnetism of iron ships and the deviations of their compasses which the construction of these models manifests.

POLLAK'S REGENERATING PILE.

POLLAK'S pile, which it is agreed is to do much in the future for telegraphy, is distinguished from all others by an ingenious combination that regenerates the couple by its own depolarization.

It consists of a vessel at the bottom of which is placed a strip of zinc bent into a circle 1⅛ inch wide by 2¼ inches in diameter, constituting one of the electrodes. The other electrode consists of a cylinder of coarse-grained, very porous carbon, of which the upper part is formed of a conglomerate of carbonaceous powder, and which is covered beneath by an electrolytic deposit of copper or other metal. This cylinder is 3⅜ inches in diameter and 3 inches in length, and is fastened to the vessel by three appendages carried by the conducting conglomerate. The necessary quantity (from 6 to 8 ounces) of sal ammoniac or pulverized kitchen salt is put into the vessel, and then water is poured in until its level is 1 or 1⅛ inch above the lower edge of the carbon.

When the apparatus is mounted, there occur in the first place, between the metallic deposit and the carbon, local actions which have the effect of decomposing the salt and bringing about other combinations with the copper. The carbon forms with its deposit a couple whose positive electrode is the copper, which, according to the nature of the liquid employed, is dissolved or partially converted into an insoluble compound; while the hydrogen set free is burned by the

oxygen condensed in the pores of the carbon. If sal ammoniac be employed, chloride of copper forms, and renders the portion of the liquid near the metal blue. This local action is what might be called the charge of the element.

It is the secondary copper-carbon couple, or rather the metal thereof, that in effect constitutes one of the electrodes of the pile. The hydrogen disengaged on the electrode thus formed is employed in the reduction of the salt, whose metallic copper it precipitates, but which is reconstituted in the presence of the carbon, and so on. It will be seen, then, that the hydrogen is indirectly absorbed by the carbon, and that the action of the latter is, as it were, regenerated by the copper.

The pile furnishes a perfectly constant current, this being due, as just seen, partially to the formation of hydrogen on the copper, and partially to the absorption of this hydrogen by the oxygen of the air condensed in the pores of the carbon. The first phase of

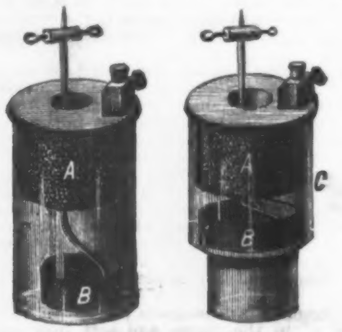


FIG. 1. FIG. 2.

POLLAK'S PILE.

this pile's work, then, has some analogy with what goes on in the Bogration element.

Such a pile, then, possesses all the qualities of the models usually adopted into which enter chemical depolarizers, but it has the advantage over these that the depolarization goes on continuously, so that it is not necessary to make the electrode any larger than is requisite for conductivity. In this pile the density of the liquid plays an important role, and it is consequently well not to shake the vessels.

EDISON'S NEW TELEPHONE APPARATUS.

NOTWITHSTANDING the success that his carbon transmitter has met with, Mr. Edison has just constructed another transmitter, which is provided with metallic contacts, and which, as a whole, slightly recalls the first form of the Reis telephone. The inventor has, however, taken the precaution to introduce into the apparatus a device that prevents the contact points from separating.

The new transmitter, although containing a liquid, like that of Gray, and other inventors, certainly does not enter the same category, since the liquid plays

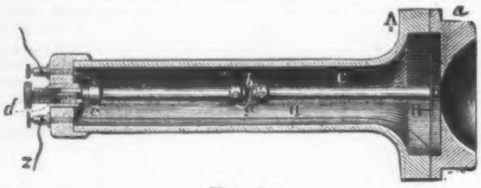


FIG. 1.

merely a mechanical role in the construction of the apparatus. It serves to limit the motions of the diaphragm, which, in its turn, limits and regulates the distance apart of the electrodes. In preventing successive motions of the diaphragm, the liquid likewise prevents too wide a separation of the electrodes, so that the latter at once return to their normal position. It is from such a position that a repercussion of all the vibration occurs.

Oil is used by preference, although any other liquid may be employed equally well, such as mercury, for example.

Fig. 3 represents the apparatus in vertical section. It consists of two parts, which inclose the diaphragm.

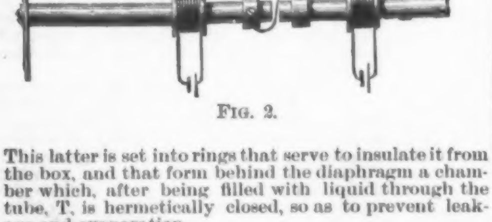


FIG. 2.

This latter is set into rings that serve to insulate it from the box, and that form behind the diaphragm a chamber which, after being filled with liquid through the tube, T, is hermetically closed, so as to prevent leakage and evaporation.

The contact points are outside of the liquid. One of them is supported by the diaphragm, while the other is mounted opposite it on a screw. This latter is permanently fixed to the box, and may be regulated by means of a rod.

For closing the telephone and preventing dampness from reaching the contact point, the apparatus is provided with a second diaphragm, which is held by the mouthpiece.

It might be asked what advantages are offered by this new form of transmitter, and whether the carbon transmitter does not give sufficiently good results. In answer, it may be remarked that the ordinary carbon contact does not, as well known, permit of the use of more than two or three pile elements. If this number be exceeded, the result will not be so good, because the contacts burn and give off sparks, even upon an insignificant motion. These sparks diminish the quickness of the vibrations, which latter must be very abrupt in order to produce a good result.

With platinum contacts, it is possible to use a more powerful current, and one that will permit of employing a much less sensitive receiver than the one now used. In this way, the induction currents that occur in all American circuits, by reason of the earth as a return conductor, will not be heard in the receiver, since they are too weak to influence it.

As a proof of what precedes, we shall mention a receiver that has been constructed by Mr. Bergmann, and which although of the same nature has no bobbin. The inventor uses one or more magnets that act upon a diaphragm, and are so arranged that the current traverses their axes. The limits within which the force makes itself felt can be varied or regulated by a special device.

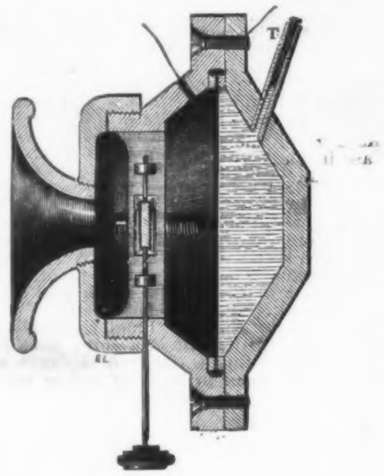


FIG. 3.

Mr. Bergmann has ascertained that the vibrations of the diaphragm correspond to the variations in the current of the axis, and that the sound harmonizes with the vibrations of the transmitter, as a consequence of variations in the magnetic intensity.

The best results have been obtained by placing two or more magnets in line, with their extremities very near each other, and connected with each other by conducting wires.

The magnets are connected in circuit, and are traversed by the current, either from one end to the other or from the center to the extremities, and *vice versa*.

Fig. 1 represents the receiver. This is very simple in construction, easily regulated, and durable. C and D are two magnetized steel bars arranged end for end, with a small intervening space, *b*. One of these is fixed to the diaphragm, and the other is supported by screw, *d*, on the outside of the box, so as to increase or diminish the space, *b*. The near extremities of the

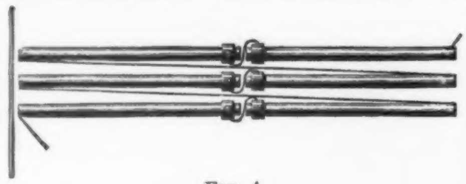


FIG. 4.

magnetized bars, C D, are connected by a conductor, *e*, so as to permit the bars to move lengthwise. The terminals, 1 and 2, are connected, one of them with the external extremity of the bar, D, through a sleeve, *c*, and the other with the external extremity of the bar, C, through the diaphragm.

The current passes from terminal 1 through the bar, D, the conductor, *e*, the bar, C, and the diaphragm, and returns to terminal 2. Its effect is to cause the diaphragm to vibrate and convert the undulations of the telephone current into articulate words.

This effect may be modified by the regulation of the screw, *d*, which varies the space, *b*.

It has been found that with two or more magnets the best results are obtained when the opposite poles of the magnets are in juxtaposition, although the instrument works likewise when the same polarities are juxtaposed. Two of the models of the apparatus especially merit description. Fig. 2 represents one in which two electro-magnets are used, and Fig. 4 shows a group of several magnets forming a magnetic circle which acts upon the diaphragm.

It is unnecessary to say that a receiver of this nature would be incapable of registering the presence of feeble induction currents, but the apparatus might possibly render good service with a powerful current.—*La Lumiere Electrique.*

MOLECULAR WEIGHT OF LIQUID WATER.

THOMSEN has called attention to the fact that the conclusion reached by Raoult in his researches on the freezing point of saline solutions, that water possesses, in the condition of liquid, twice the molecular weight which it has in the condition of vapor, coincides with the conclusion to which he himself had come from his investigations on the constitution of hydrated salts. In his thermo-chemical researches, Thomsen says: "A glance at the table of heat of hydration of hydrated salts shows that the water molecules enter often in pairs with the same heat change; a fact explicable either by supposing that the molecules of water are symmetrically placed in the molecule of the salt, or, and perhaps more probably, that the molecular weight of liquid water is twice that of water vapor. The similarity of these conclusions, from widely different fields of investigation, is noteworthy.—*Ber. Berl. Chem. Ges.*

FEHLING'S LIQUOR AS A REAGENT.

FEHLING'S liquor, according to the proportions used, may indicate the presence of peptones, of uric acid in excess, of phosphoric acid in excess in urines respectively poor or rich in uric acid, and of glucose. If 1 c. c. of Fehling's liquor is mixed with 8 to 10 c. c. of urine, shaken up, and boiled, the liquid may remain blue, which signifies nothing. But if it is decolorized, with a pale yellow flocculent precipitate floating in the liquid, peptone is present. If the liquid turns orange and there is an orange precipitate, we have glucose.

If equal parts of Fehling's liquor and urine are mixed in a test-tube and boiled, and the clear liquid remains blue, there is little uric acid. If it becomes green, the urine contains an excess of uric acid or of a urate. If the precipitate is scanty, there is little phosphoric acid; but if copious, phosphoric acid is present in excess.—*L. Jolly.*

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